INQUIRY & INVESTIGATION

"Uncooking" a Traditional DNA-Extraction Laboratory from the Scientific-Practices Perspective

RECOMMENDED FOR AP Biology

KADIR DEMIR

Abstract

This transformed DNA-extraction lab activity offers a framework that strategically draws upon the essential elements of both scientific and effective teaching practices to establish an alternative approach to the teaching and learning of science. The pedagogical methods utilized throughout this activity encourage students' motivation, engagement, and learning through inquiry-based, teacher-facilitated scientific practices. Additionally, this activity emphasizes Dimension 1 of the Framework for K–12 Science Education *(Scientific and Engineering Practices; National Research Council, 2012). In the activity, students worked in groups and were allowed to examine different traditional lab protocols and other resources. The students had the freedom of selecting an independent variable that could possibly have an effect on the DNA extraction. To demonstrate how this activity was implemented in the classroom, a running vignette of a DNA-extraction activity in a high school biology class, in which the teacher adhered to the elements of this framework, is included.*

Key Words: *Inquiry-based teaching; scientific practices; DNA extraction; effective teaching.*

○ Introduction

The performance of students in science, technology, engineering and mathematics (STEM) has been of great concern in the United States, because STEM majors are crucial disciplines for the nation's economic development, prosperity, and security. In the *Trends in International Mathematics and Science Study*, 15% of U.S. fourth-graders (among 36 countries or educational jurisdictions) and 10% of U.S. eighth-graders (among 48 countries or educational jurisdictions) scored at or above the advanced international benchmark in science (National Center for Education Statistics [NCES], 2007). Nationally, most of the students who took the 2009 National Assessment of Educational Progress science assessment failed to reach the proficient level: for example, 34% of fourth-graders, 30% of eighth-graders, and 21% of 12th-graders performed at or above the proficient level in science. The results for minorities and low-income students are even lower. By grade 12, only 4% of black students, 8% of Hispanic students, and 8% of low-income students reached the proficient level (NCES, 2011).

It is commonly held that teachers are the most important factors in student learning (National Research Council [NRC], 2001). According to the NRC (2012), by the end of grade 12, students need to develop an appreciation of the beauty and wonder of science, possess sufficient knowledge of science and engineering to engage in public discussions on related issues, and become careful consumers of scientific and technological information related to their everyday lives. In the centuries since April 23, 1635 – the day that the Boston Latin School, the first public school in the United States, was established – little has changed in teachers' practices, despite the fact that today's classrooms offer more luxuries and are better equipped with technology. Classrooms continue to be designed in ways that encourage teachers to enact the traditional "sage on the stage," rather than the "guide on the side" pedagogy that uses interactive technology to engage learners. In a typical class, students spend most of their time listening to the teacher, taking notes, and/or working alone on low-level worksheets and learning discrete skills. Students become increasingly compliant in their learning, viewing it as their responsibility to match their own meanings to those expected by the teacher (McCaslin & Good, 1992). Memorization is stressed at the expense of critical thinking. Frequently, reading about science takes the place of doing science, and learners are not provided with engaging opportunities to experience how science is actually done. Further, learners are often deprived of opportunities to develop decision-making,

Reform-oriented practices call for the establishment of student-centered environments for teaching and learning science, wherein the learner actively constructs meaning.

The American Biology Teacher, Vol. 78, No 7, pages. 582–590, ISSN 0002-7685, electronic ISSN 1938-4211. © 2016 National Association of Biology Teachers. All rights reserved. Please direct all requests for permission to photocopy or reproduce article content through the University of California Press's Reprints and Permissions web page, www.ucpress.edu/journals.php?p=reprints. DOI: 10.1525/abt.2016.78.7.582.

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

metacognition, and attention-checking skills necessary to enhance learning experiences (Perkins, 1993). As a result of ineffective traditional teaching and learning practices, students are leaving high schools without meeting benchmarks outlined by reform documents (e.g., NRC, 2012).

Reform-oriented practices call for the establishment of student-centered environments for teaching and learning science, wherein the learner actively constructs meaning. In such environments, students' learning outcomes may be established, but the learners decide how to continue on the basis of their individual needs and the questions they have developed while generating and testing viewpoints (Hannafin et al., 1999). Such environments benefit learners in many ways. For example, learners (1) are engaged in powerful pedagogical practices that enhance their understanding of science content; (2) are involved in fundamental questions about the world and with how scientists have investigated and found answers to those questions; (3) become critical consumers of scientific knowledge linked to their everyday lives and continue to learn about science throughout their lives; and (4) develop a deep understanding of the nature of science (NRC, 2000, 2012). Such learning environments, tacitly or explicitly, are supported to echo constructivist epistemologies (Jonassen, 1999).

Knowledge, thinking, and the contexts for learning are indistinguishably intertwined (Brown et al., 1989). While all learning is contextually based, not all contexts support the use of knowledge equally. For instance, knowledge attained in decontextualized situations is inclined to be inert and of little practical use. Thus, student-centered pedagogical practices involve a reformulation of learning environments to reflect these intertwined relationships that can be contemplated as authentic science. Roth (1995) regarded authentic science activities as parallel to what scientists do in a community of practice. According to Roth, such practices are focused on ill-defined problems; ambiguity requires students to delineate the tasks and subtasks needed to understand and complete the activity. Learner-centered pedagogical practices afford shared, complementary activities that empower individuals to address unique learning interests and needs, study various levels of complexity, and strengthen understanding of the phenomena being studied (Hannafin & Land, 1997). Further, these pedagogical practices are designed to support individual efforts to negotiate meaning while engaging in authentic activities.

Constructivist epistemologies are extensively advocated but rarely practiced in classroom learning environments (Demir & Ellett, 2014). Scholars recommend various models to establish authentic science practices for learners (e.g., simulation vs. participation model; Barab & Hay, 2001). In a simulation model, learners are encouraged to carry out scientific practices as scientists do, but within a designed classroom environment similar to a community of practice. Here, I provide an example of a reform-based teaching and learning activity that is reflective of a simulation model. This activity is a good example of how authentic science practice is being infused in a secondary-school laboratory setting.

○ Overview

A reformed teaching framework (RTF) that includes scientific practices (NRC, 2012) and learner-centered practices, via elements of evidence-based effective teaching practices, would be instrumental in helping transform today's classrooms from dull, bleak places into creative spaces of engagement, critical thinking, and problem solving. RTF strategies draw upon the NRC's essential features of scientific practices, which assert that students should

- Engage with scientifically oriented questions
- Develop and use models
- Plan and carry out investigations
- Analyze and interpret data
- Use mathematics and computational thinking
- Construct explanations
- Engage in argument from evidence
- Obtain, evaluate, and communicate information

The RTF approach is also guided by the five effective science instructional strategies outlined by Koballa & Demir (2010), which include motivation, use of prior knowledge, intellectual engagement, use of evidence, and sense making.

So, what might a science classroom look like if the RTF is incorporated into the regular learning environment? One would expect to see more emphasis placed on student-centered teaching and learning practices than might be seen in typical, teacher-centered classrooms. The RTF shifts learning from the teacher-centered model of lecturing to an inquiry-based, teacher-facilitated model, leading students to build upon core content knowledge through problem-solving, interpersonal, and self-directional skills. Here, I present a reenactment of a biology unit that was prepared and delivered by Ms. Crawford around the elements of the RTF. It illustrates how student questioning, interpretations, reflections, and teacher guidance lead to active learning outcomes.

Description of the Context

Ms. Crawford is a biotechnology teacher at a career and technical education facility. (The names given to the teachers and students are pseudonyms.) The facility is located in a midsize midwestern town with an approximate population of 80,000. This facility serves students from multiple high schools both inside and outside the county's school districts. The unit that I observed was about the topic of genetics in animals, plants, and bacteria. The class had six students in it – four seniors, one junior, and one sophomore. These included five Caucasian students (four females and one male) and one African American female. My observation period in Ms. Crawford's class included 10 class blocks of 90 minutes each, yet the activity reported here was spread over three classroom periods. A portion of the first two periods was used to allow students to explore the topic and provide them with resources to complete the task. The third period was dedicated to the completion of the laboratory activity and the presentation of findings.

As a high school student, Ms. Crawford learned science via a textbook approach. Class lectures were infrequently punctuated with textbook-based experiments and required great imagination to connect the scientific principles to examples beyond the classroom. In graduate school, she realized that science is an ongoing process of investigation, questioning, data collection, data analysis, and more. Then she became cognizant that critical thinking, problem-solving skills, and innovation are some of the essential ingredients for students to learn and experience in science classes if they are to make sense of science. In addition to having a genuine interest in meeting

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

the academic needs of her students, she also wanted to create innovative ways to pique their interest in STEM subjects and careers. Thus, she dedicated much instructional time to familiarizing her students with research methodologies, types of laboratory technologies, and work skills that they were likely to encounter in the future. This complemented their strong foundational base of scientific knowledge. Before visiting Ms. Crawford's class for a student-centered DNA-extraction lab, let's look at how such labs are typically taught.

DNA-Extraction Activities in Traditional High School Biology Classrooms

In DNA-extraction labs, students use technology and engineering processes to isolate DNA from cellular materials. In reference to eight practices that are considered essential for learning science in grades K–12 (NRC, 2012), I examined the following three DNA-extraction labs:

- Lab A: Strawberry DNA-extraction lesson plan. Retrieved March 19, 2014 from http://gemsclub.org/yahoo_site_admin/assets/docs/StrawberryDNAExtra.4395135.pdf
- Lab B: Fruit DNA extraction. Retrieved March 15, 2014 from https://haitibio.squarespace.com/s/fruit-dna.pdf
- Lab C: DNA extraction from kiwifruit. Retrieved March 15, 2014 from http://www.sas.upenn.edu/~upshaw/kiwi.pdf

I found that these labs are organized around five familiar steps: purpose, procedure, data, analysis, and conclusion. Their purpose statements include the objective of the activities (e.g., to demonstrate ways to extract DNA from different sources, such as fruits) and an explanation of the underlying use of DNA extraction in forensic science. The labs are heavily teacher-directed and allow very little, if any, opportunities for student inquiry or reflection. Students usually receive step-by-step instructions on how to conduct the lab, what to observe, and how to interpret the findings. Table 1 provides a brief summary of observations that reflect whether the aspects of Lab A (strawberry DNA extraction; see Appendix) include essential features of scientific practices. It is clear that this lab does not reflect essential features of inquiry-based teaching and learning.

Traditional teaching and learning pedagogy often results in students getting the *right* answers, but it also often results in limited student learning. This form of instruction lacks opportunities for students to generate questions, connect the science concepts to their everyday lives, or engage in decision-making processes regarding the design of the lab and what data to collect. When students have opportunities to develop their ideas through active questioning and critical thinking, they construct meanings and have enriched learning experiences that deepen their understanding of scientific concepts and skills. To complete science labs, the teacher guides the students through the activity, giving the students ample opportunities to discuss and justify their ideas in small groups, provide preliminary evidence-based explanations, explain and evaluate their reasoning orally and through writing, and change their ideas in light of the evidence. This explanation-and-evaluation stage is important, though many teachers often skip it, resulting in incomplete student understanding of scientific concepts.

Table 1. Essential features of Scientific Practices (NRC, 2012) compared with the contents of Lab A (strawberry DNA extraction; see Appendix).

	Scientific Practices	Lab A – Author's Analysis
1	Asking questions for science	The purpose statement does not include a scientifically oriented research question. It does not appear that students are/will be involved in generating questions or connecting the concept of DNA to their lives.
2	Developing and using models	The lab does not allow learners an opportunity to construct mental or written models of DNA. This limits their ability to test or pose a hypothesis.
3	Planning and carrying out investigation	The activity provides opportunities for learners to use their senses to collect data and make judgments about the texture and appearance of extracted DNA; however, learners do not decide what data to collect and how to collect it. Learners have no control over variables.
4	Analyzing and interpreting data	
5	Using mathematics and conceptual thinking	Learners use no mathematical computation, simulations, or calculations of their data (i.e., DNA percentage yield).
6	Constructing explanations for science	Learners have no opportunity to offer preliminary explanations on aspects of DNA extraction that may have an impact on the percentage yield. This limits learners' opportunity to explain their reasoning or demonstrate their understanding of the concept.
7	Engaging in argument from evidence	Because learners do not construct explanations for aspects of DNA extractions, they cannot form arguments, the strength of which must be grounded in their line of reasoning.
8	Obtaining, evaluating, and communicating information	Learners have no opportunity to evaluate their thinking or change their ideas in light of the evidence in hand. Learners have no opportunity to discuss their ideas in small groups or to justify their ideas either through writing or speaking.

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

An Alternative to the Traditional DNA-Extraction Lab

You are now invited to learn about a student-centered activity that Ms. Crawford implemented using the RTF. This unit was designed to help students develop essential understanding of basic mechanisms of DNA and RNA, particularly how these two elements control inheritance, and how they differ among animals, plants, bacteria, and viruses. Here, I will focus on one particular segment of the unit, the DNA-extraction activity. Tables 2–5 present my classroom observation data as a running vignette of what was happening in Ms. Crawford's classroom and how that was related to elements of the RTF. Although multiple elements (e.g., teacher as facilitator, use of motivation, and intellectual engagement) occurred throughout the activity, only the most pertinent ones are listed, to avoid redundancy.

Table 2 shows that Ms. Crawford dedicated the beginning of the activity to assessing and activating the students' prior knowledge by reviewing key genetic terms, asking review questions, and bringing attention to the unique aspects of science, engineering, and technology. These actions help the facilitator guide the inquiry process.

The students had unlimited access to the appropriate resources during the activity. This thematic activity allowed students to frame their research questions, take ownership, and engage intellectually in all aspects of the problem-solving process that they wanted to investigate. These questions are similar to those that scientists seek answers to while conducting their research. Interestingly, each group developed different strategies to perform their inquiry that allowed for differentiation of learning to naturally occur. While serving as a facilitator, Ms. Crawford incorporated several motivational strategies promoted by Koballa and Demir (2010) (challenge, curiosity, creativity, choice, cooperation, connection) in her instruction (see Table 3). Ms. Crawford *challenged* by probing students' understanding and asking questions that required critical-thinking skills; encouraged *curiosity* by asking students to question and solve ambiguities associated with their work; incorporated *creativity* through emphasizing divergent thinking by allowing student groups to design their own questions and research protocols and to put their original stamp on their work; established *choice* by giving her students more opportunities to make selections and decisions about their learning and letting them explore phenomena in ways that worked best for them; promoted *cooperation* through the use of small groups, which facilitates student collaboration; created *connection* by making the pre-lab activities meaningful by contextualizing them and connecting them to students' everyday experiences.

Let's take a peek into the classroom and observe the interactions that occurred between Ms. Crawford and her students while they executed their DNA-extraction inquiry protocols (see Table 4). As is apparent in Table 4, the students' sense-making conversations included reframing questions, offering explanations, and rebuffing explanations with alternative arguments, all of which are central to processing and understanding in inquiry pedagogy. To facilitate these sense-making discussions, Ms. Crawford used open questions and discourse patterns that encouraged students to actively question and apply the evidence from their research protocols. The classroom environment that Ms. Crawford established encouraged students to make predictions, draw relationships, rethink their research designs, relate cause and effect, and draw conclusions. The students' conversations indicated that they were reflecting on and applying their new knowledge to a situation of which they had little prior understanding. Providing students with novel situations and encouraging them to apply ideas with which they have been engaged is a hallmark of teacher practice shown to promote sense making. This discourse provided students

Table 2. Getting started: identifying the focus of the DNA-extraction activity in Ms. Crawford's class, as observed by the author, within a reformed teaching framework (RTF).

Observation Data: What Is Happening in the Classroom?	Elements of RTF
Ms. Crawford organized the class into groups of three or four students and challenged each group to design and perform an experiment that efficiently obtains DNA, measured by percentage yield, from different sources without breaking down genetic material.	• Use of Prior Knowledge • Teacher as Facilitator
Prior to the lab, Ms. Crawford required everyone to review online materials that she considered basic for the understanding of genetics. These included some interactive online materials that used visuals to illustrate the presence of genetic material in plants, animals, and human beings as well as other related topics such as stem cells, gene therapy, and cloning (http://learn.genetics.utah.edu/). Also, she handed the students three traditional DNA-extraction protocols to read.	
On the first day of the lab, Ms. Crawford went through a few review questions to help her assess students' background knowledge and readiness for the forthcoming lessons. She asked them to think about the structure of eukaryotic cells and how they differ between animal cells and plant cells:	
• What barriers have to be overcome in order to isolate DNA from animal cells? Plant cells? • What are the similarities and differences between the three DNA-extraction lab protocols that you have been given? • What are the three major things that must be accomplished in order to extract DNA? • Where do we see the engineering and technology portions of this lesson (skills or tools needed)?	
When she was confident that they were prepared for the upcoming unit, she proceeded with the next step.	

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

Table 3. Establishing criteria and guidance within a reformed teaching framework (RTF) in Ms. Crawford's class, as observed by the author.

Observation Data: What Is Happening in the Classroom?	Elements of RTF
Next, Ms. Crawford revisited questions 3 and 4 from the review session to challenge the students to design a protocol to extract DNA, measured by percentage yield, from different sources without breaking down genetic material. To probe their thinking, she asked the students to think about aspects of DNA extraction that may have an impact on the percentage yield.	• Intellectual Engagement • Motivation • Student-Generated, Scientifically Oriented Research Questions • Developing and Using Models • Planning and Carrying Out Investigation • Teacher as Facilitator
Ms. Crawford wanted to ensure that the students knew what they were doing. She provided all the groups with a handout with guidelines and factors they should consider in designing their protocols. She monitored their work and provided them with the help and support they needed in designing their protocols.	
In their groups, students came up with some of the following questions to investigate: • Is there a relationship between the amount of DNA obtained from chicken liver and the meat tenderizer brand used in the extraction process? • Is there a relationship between the amount of DNA extracted and the detergent used? If so, what differences among the detergent brands might have yielded different results? • Are there any differences in the amount of DNA extracted from a fruit or vegetable other than bananas?	
Once the students had a research question and Ms. Crawford approved their experiment protocols, it was time to start their labs. However, prior to actually beginning the labs, to prime students' prior knowledge of instrument use, Ms. Crawford reviewed the procedures for proper use of the equipment involved in DNA extraction, such as pipettes and spectrophotometer. She also asked students to demonstrate their ability to calculate serial dilution factor and percentage yield, learned earlier in the semester. Lastly, she introduced and discussed the expected outcomes: • Assessment • Final product: Poster presentation and science notebooks • Careful and appropriate construction of scientific investigation ∘ Clearly presented information (logical flow, main components of research question, procedure, data, analysis, and conclusion) ∘ Clear connection between the question(s) investigated and the conclusiono ∘ Evidence-based conclusion	

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

Table 4. Classroom discourse in Ms. Crawford's class, as observed by the author, within a reformed teaching framework (RTF).

Observation Data: What Is Happening in the Classroom?	Elements of RTF
Teacher: What you guys are saying is that you have different requirements here because of the nature of your experiments. So, can we compare sources at the end? **Ashley:** It is going to be hard even if we had the same amount. It is not because each thing has different amount [referring to DNA], it is because we have different protocols. **Jessica:** That is what she is saying [referring to the teacher] . . . we are going to compare, using one method, how much DNA can we get out. **Teacher:** What would be another way to compare how efficient chicken livers versus bananas, versus kiwi per gram of material would be? **Kara:** Just take all the measurements all the way through every single thing . . . [pause] . . . compare how much you had to start out with and how much you ended up with. **Teacher:** And convert it to? **Kara:** Convert it to whatever you need to milligram, milliliter, grams . . . we have to decide on it. **Jason:** You said that every scientist has different opinions on how to extract DNA, and for different purposes there is a method that works best. Is that what you want to get us to do? Like having our little arguments . . . if you are making us come up with our own procedure then you need to have it the way we have it right there [pointing to the board]. If you are trying to see what makes it yield the most then we need to have it uniform and we need to change one thing. Like if the meat is used as	• Sense Making • Mathematics and Conceptual Thinking • Constructing Explanations for Science • Engaging in Argument from Evidence • Teacher as Facilitator

Table 4. Continued

Observation Data: What Is Happening in the Classroom?	Elements of RTF
the source of DNA that would be the independent variable. Everything else would stay the same. Or if we all want to use bananas we would change how we break up cell membrane that would be our independent variable. So, what are you trying to get us to do? **Teacher:** What I had in mind was that I wanted you to discuss and tweak it around a little bit [pause] as you all do simple percent recovery. **Aimee:** What do you mean? **Teacher:** You take your beginning mass of your material. Like you weigh out 30 g of bananas and do whatever you are going to do . . . when you get to the end you should be able to tell how much you recovered from your variables. So out of my 15 g bananas over here I recovered so much DNA. It is this percent from this many grams of bananas with this protocol I recovered this percent. So, that allows you to compare your variables, but it also says you guys got like 1% recovery.	

Table 5. Closure and assessment in Ms. Crawford's class, as observed by the author, within a reformed teaching framework (RTF).

Observation Data: What Is Happening in the Classroom?	Elements of RTF
In the final part of the lab, the students performed their experiments and analyzed the data they had collected within their groups. They modified their experiments, as needed, based on the evidence obtained. They drew some conclusions from that in order to apply it to the next step. They talked among themselves about what worked and what did not work for the teams that sat in front of and behind them. They collaborated with other teams to share data and ask questions. While Ms. Crawford was facilitating the activities, she could see that the students were adjusting their protocols to take into account the limitations and other factors that they had not initially considered. Ms. Crawford seemed happy to see this happening and reminded the students to record their adjustments with explanations.	• Obtaining, Evaluating, and Communicating Information • Teacher as Facilitator
At the end, not all of the groups were able to obtain DNA from their sources. One such group got frustrated and commented that they had failed to meet Ms. Crawford's expectations. Jason raised his voice and yelled at his classmates a few times to express this frustration. One student was also worried, but she was calm. She asked Ms. Crawford if they could redo their experiment. Ms. Crawford assured them that it was okay if they did not end up with the outcome they had wanted. Ms. Crawford advised them to focus on the evidence they had in their hands – the observable differences, such as color and consistency. She asked that they record and report every single step taken during the procedure. "You always have results. They may not be the ones you wanted or they may not make sense to you at that moment, but no result is still a result," she instructed.	
As a culminating activity, each group presented a research claim to the class. The claim consisted of their question, their observations, and an evidence-based explanation that identified the variables responsible for rusting. Subsequently, students were allowed to challenge other students' claims.	

opportunities for self-assessment of their understanding in addition to providing Ms. Crawford multiple forms of formative assessment. This is essential in developing student reflection upon and evaluation of their scientific practices.

Subsequently, as outlined in Table 5, the students recorded their observations and discussed emerging patterns in a class discussion. This created interaction among the team members and across various teams. Students used the data as evidence to support their new scientific understandings of what was happening in the inquiry activity. When there were inconsistencies between their understandings and their observed data, they asked Ms. Crawford for assistance, which she readily provided. This inquiry-based process of learning stimulated the students' understanding of scientific phenomena by using evidence and allowed them to be active agents in their learning. By prioritizing the process of seeking answers themselves rather than focusing on finding the right answer, the students learned as much from their mistakes as they did from all other aspects of this activity. They became more attentive to the value of evidence to endorse and refute claims and the implications that evidence might have for further studies. It allowed them to view exploration and scientific knowledge as a process, rather than an end result.

Ms. Crawford devoted the last part of the class to knowledge application and reflection. Students synthesized what they had learned about investigating their own questions. While working on the final presentations, the teams put in a great deal of time and effort to make their posters scientifically correct, visually appealing, and representative of their personalities. During the poster session, students shared their research with one another,

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

including those who were not successful in extracting DNA, because those students' experiences were also valid and valuable. As they listened and viewed their peers' completed work, they asked questions and discussed what implications the findings had for further studies if they were to do it over again. Some examples of questions posed by the students to their classmates during the presentations were

- How did your results compare to what you had hypothesized about meat-tenderized brands? How could we assure that?
- What kind of claims can we make about the amount of DNA extracted from different sources – fruit, vegetable, and chicken liver?
- Did you record the ethanol's temperature to observe its effect on precipitating (or solidifying) the DNA?

And the teacher considered the following questions to determine whether students were bridging context and past experiences as they constructed evidence-based explanations:

- Could you explain your reasoning?
- Can you compare your explanations based on how well they account for the evidence?
- How would you revise your explanations in light of evidence?

The group presentations afforded students the opportunity to present their findings and provided a platform for students to contemplate possible issues and address those that arose during the activity. Overall, this activity resulted in students developing understanding of the variables affecting DNA extraction. After all groups presented and shared their findings and evidence-based claims, the teacher summarized the findings by providing a scientific explanation of reagents involved in DNA extraction and percentage yield.

Discussion and Conclusion

Scientific practices in the classroom must have an underlying structure to provide for classroom management, evidence-based outcomes, and clearly defined expectations. Along the way, rigorous and thoughtful guiding questions should be asked, to challenge and refocus students' scientific thinking while also checking the design of the investigation. With the new emphasis on engineering and technology (NRC, 2012), students will likely confuse these ideas with what science is and how science works. It will be important to explicitly tease out the aspects of these separate practices through discussion and reflection.

The reformed strategies were developed as an alternative instructional model to traditional practices. They were born of the belief that engaging students is important and could be accomplished through active construction of ideas. Essential elements of scientific practices (NRC, 2012) are instilled in the classroom via elements of effective science teaching (Koballa & Demir, 2010). Ms. Crawford had high expectations of her students. She communicated the confidence that she had in them, while providing challenging but attainable learning goals. The students immersed themselves in an investigation of their own research questions. They learned to think, ask questions, conduct experiments, interact with each other in increasingly knowledgeable ways, and make inferences from their data. This resulted in increased student engagement in learning. Lastly, Ms. Crawford addressed design principles for developing and evaluating an authentic scientific practice task as identified by Herrington et al. (2003), including real-world relevance; an ill-defined problem, requiring students to define the tasks and subtasks needed to complete the activity; the opportunity for students to examine the task from different perspectives, using a variety of resources; the opportunity to collaborate; and the opportunity to reflect.

The need for better-quality science teaching and increased student learning and achievement outcomes is unavoidable, given the current status of student achievement results in science. Although the described activity occurred in a biotechnology classroom, it is an innovative example that should be considered for use by high school biology teachers. I hope that this article will provide an example that moves teachers toward the use of reform-based teaching and learning environments.

Loucks-Horsley et al. (2003) view change as progressive, occurring through "active engagement with new ideas, understandings, and real-life experiences" (p. 39). Smith et al. (2003) delineate teacher change as differences in thinking and acting on and off the topic: change *on* the topic (e.g., new teaching practices) embraces enhanced knowledge about the topic and reported action taken to address learner persistence in the classroom; change *off* the topic comprises increased confidence in teaching, decreased feelings of isolation, and increased use of a new teaching technique. If science teachers are to envision moving toward a more reform-oriented stance, they need to have access to field-tested and successfully implemented examples of scientific practices in both lecture and laboratory settings. Thus, they can begin to build an understanding of how scientific practices can be structured and how students respond to these practices. Innovations in science teaching and learning environments need to be accompanied by empirical studies of outcomes, because science teachers value evidence in making decisions. Evidence about the gains in student knowledge of science content, understanding of scientific practices, and ability to carry out scientific practices as a result of innovations in instruction could, ultimately, help persuade science teachers to change their practices.

References

Barab, S.A. & Hay, K.E. (2001). Doing science at the elbows of experts: issues related to the science apprenticeship camp. *Journal of Research in Science Teaching, 38,* 70–102.

Brown, J.S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Demir, K. & Ellett, C.D. (2014). Cross-cultural research and perspectives on epistemology, learning environments, and culture. In R. Evans, J. Luft, C. Czerniak & C. Pea (Eds.), *The Role of Science Teachers' Beliefs in Classrooms: International Research and Implications for Policy and Educators* (pp. 179–190). Rotterdam, The Netherlands: Sense.

Hannafin, M.J. & Land, S.M. (1997). The foundations and assumptions of technology-enhanced, student-centered learning environments. *Instructional Science, 25,* 167–202.

Hannafin, M.J., Land, S.M. & Oliver, K. (1999). Open learning environments: foundations, methods, and models. In C. Reigeluth (Ed.), *Instructional-Design Theories and Models* (vol. 2, pp. 115–140). Mahwah, NJ: Lawrence Erlbaum.

Herrington, J., Oliver, R. & Reeves, T.C. (2003). Patterns of engagement in authentic online learning environments. *Australian Journal of Educational Technology, 19,* 59–71.

Jonassen, D. (1999). Constructivist learning environments. In C. Reigeluth (Ed.), *Instructional-Design Theories and Models* (vol. 2, pp. 215–239). Mahwah, NJ: Lawrence Erlbaum.

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

Koballa, T. & Demir, A. (2010). Making high school science instruction effective. In J. Devitis & L. Irwin-DeVitis (Eds.), *Adolescent Education: A Reader* (pp. 243–258). New York, NY: Peter Lang.

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S. & Hewson, P.W. (2003). *Designing Professional Development for Teachers of Science and Mathematics, 2nd Ed*. Thousand Oaks, CA: Corwin Press.

McCaslin, M. & Good, T. (1992). Compliant cognition: the misalliance of management and instructional goals in current school reform. *Educational Researcher, 21*(3), 4–17.

National Center for Education Statistics (2007). *Trends in International Mathematics and Science Study (TIMSS)*. Washington, DC: U.S. Department of Education.

National Center for Education Statistics (2011). *The Nation's Report Card: Science 2009*. Washington, DC: U.S. Department of Education.

National Research Council (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council (2001). *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium*. Washington, DC: National Academy Press.

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

Perkins, D.N. (1993). Person-plus: a distributed view of thinking and learning. In G. Salomon (Ed.), *Distributed Cognitions* (pp. 88–110). New York, NY: Cambridge University Press.

Roth, W.-M. (1995). *Authentic School Science: Knowing and Learning in Open-Inquiry Science Laboratories*. Dordrecht, The Netherlands: Kluwer Academic.

Smith, C., Hofer, J., Gillespie, M., Solomon, M. & Rowe, K. (2003). *How Teachers Change: A Study of Professional Development in Adult Education* (NCSALL Reports No. 25). Cambridge, MA: National Center for the Study of Adult Learning and Literacy.

KADIR DEMIR is an Associate Professor of Science Education at Georgia State University, 30 Pryor Street (Suite 600), Atlanta, GA 30303; e-mail: kadir@gsu.edu.

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021

Appendix

Name________________________ Date________________________

DNA Extraction: Strawberry

Background: The long, thick fibers of DNA store the information for the functioning of the chemistry of life. DNA is present in every cell of plants and animals. The DNA found in strawberry cells can be extracted using common, everyday materials. We will use an extraction buffer containing salt to break up protein chains that bind around the nucleic acids, and dish soap to dissolve the lipid (fat) part of the strawberry cell wall and nuclear membrane. This extraction buffer will help provide us access to the DNA inside the cells.

Pre-lab questions:

1. What do you think the DNA will look like?
2. Where is DNA found?

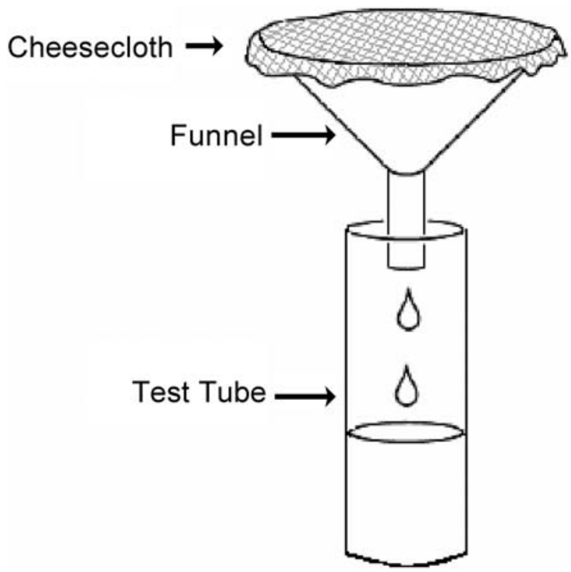
Materials:

Heavy duty ziploc bag
1 strawberry
10 mL DNA-extraction buffer (soapy, salty water)
Cheesecloth
Funnel
50 mL vial / test tube
Glass rod, inoculating loop, or popsicle stick
20 mL ethanol

Procedures:

1. Place one strawberry in a Ziploc bag.
2. Smash/grind up the strawberry using your fist and fingers for 2 minutes. *Careful not to break the bag!!*
3. Add the provided 10mL of extraction buffer (salt and soap solution) to the bag.
4. Knead/mush the strawberry in the bag again for 1 minute.
5. Assemble your filtration apparatus as shown to the right.
6. Pour the strawberry slurry into the filtration apparatus and let it drip directly into your test tube.

7. Slowly pour cold ethanol into the tube. OBSERVE ☺
8. Dip the loop or glass rod into the tube where the strawberry extract and ethanol layers come into contact with each other. OBSERVE ☺



UNIVERSITY COLLEGE
The Smartest Choice in Continuing Education

Washington University in St. Louis

M.S. IN BIOLOGY FOR SCIENCE TEACHERS
Designed for working teachers, this two-year program combines online courses during the academic year and a unique on-campus institute for three weeks over the summer.

Learn more online at
ucollege.wustl.edu/MSinBiology

Downloaded from http://online.ucpress.edu/abt/article-pdf/78/7/582/65463/abt_2016_78_7_582.pdf by guest on 26 January 2021