Applying the Iterative Nature of the Scientific Process

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Overview

The scientific process is built into multiple facets of our lives. It can be applied to the decisions and conclusions we make every day. This is critical since these decisions have such a significant impact on the way we live. The scientific process provides us with the necessary knowledge to make critical life decisions. My unit will focus on the iterative nature of the scientific process, which should bring my students closer to achieving a complete understanding of its purpose and practices. Therefore, my students will engage in activities and practices that reinforce the cyclical processes of science. In my experience, the best way to get students to achieve this level of understanding is by breaking down the information into parts. Accordingly, my students will be able to build on their understanding by first mastering the focus of this unit.

It is important to recognize the dynamic conditions in which I work to fully appreciate my methods. I teach Biology and Physical Science at South Philadelphia High School. My students come from very diverse ethnic backgrounds, with the population being 57% African American, 28% Asian, 8% Latino, and 6% Caucasian. While they are diverse ethnically, they are parallel economically with 85% of them considered to be economically disadvantaged or low-income. Moreover, 30% of the students are English Language Learners (ELL). This presents a dynamic in the school that is both exciting and intimidating. As one could imagine, differentiating a lesson for a group this diverse can be quite challenging. However, there differences can also be used as an asset to reinforce the similarities they share.

One of my goals with this curriculum unit is to expose my students to the similarities they share with each other. A major similarity I expose them to is the process they use to solve problems. This will be highlighted through the process of science. In particular, I would like my students to focus on the way modifications and revisions to initial preconceptions can lead to discovery of new ideas. This understanding should help alleviate the frustration they exhibit when they face obstacles or obstructions with the process. This will occur because they will learn that the obstacles they encounter are mere steps along the way that must be followed to master the practices of the process. Utilizing this theme can help them strengthen their appreciation for the methods used to derive theories and laws. It will also help them identify that the process used for discovery is one that can be duplicated by anyone. Thus, reinforcing the idea that the scientific process is universal and repetitive. Optimistically, they will be able to relate the concepts to their own lives and recognize when the process is applicable.

Thus far, my research leads me to believe that the iterative practice of the scientific process is quite effective when used to solve problems and make discoveries. Since discovery and problem solving are a major part of what science is about, focusing on these ideas will help students make sense of the process. It is effective because it establishes that a cycle is the mechanism for the process. The behavior of a cycle reinforces the idea that there is a pattern the process follows. Theoretically, a pattern implies that the same event or behavior will be repeated over and over infinitely. In regards to science, it is not that the same exact procedures will be followed but that general process will be repeated with modifications and revisions included until theories or laws are established. More specifically, the iterative practices in this unit will help them understand how the conclusions of one experiment can lead to the purpose or question that begins another experiment. Ideally, this pattern could go on forever, continuing to produce experiments that lead to discovery.

I expect to accomplish this by aligning my curriculum unit with several common core standards from the School District of Philadelphia. The standards will serve as a tool of guidance facilitating the execution of each stage of the unit. It will also provide the necessary structure to keep pace with the district's scheduling and timeline. The content of the unit will not focus on anyone of these particular standards but touch on all of them at any point throughout the unit, thus giving the students a complete understanding of the material. If executed correctly, each standard should reinforce the idea that science is iterative by nature eventually leading to the discovery of the theories and laws that govern our life. The list below identifies the standards will be used throughout the unit to ensure that students are achieving mastery of the content:

> 3.1.10.A: Discriminate among the concepts of systems, subsystems, feedback and control in solving technological problems.
> 3.1.10.C: Apply patterns as repeated processes or recurring elements in science and technology.
> 3.2.10.C: Apply the elements of scientific inquiry to solve problems

Rationale

There are many concepts that are critical to understanding the scientific process. These concepts lay the foundation for discovery and advancement in the fields of Science. To appreciate the scientific process, students must be able to identify the all the important parts of the process, and in return, relate those parts to the significance of the whole or entirety of the process. It is difficult to argue that the scientific process is irreducibly complex, however there is no denying that most conclusions in the process depend heavily on the different parts leading up to the end results of the process. With that in mind, my students will focus on how those individual parts build on each other until a summative concept is realized, thus demonstrating the iterative nature of the scientific process. The iterative practice, inherent in the scientific process, is an essential practice for Scientist. It allows Scientist to build on the own experiences and interpret the significance of their findings (Oppermann, 2013).

The iterative practice also has many other applications that my students may find useful in life. Examples of the iterative process can be found throughout many different facets of our lives. This makes the iterative process an essential tool for learning in general rather than just an effective tool Scientist can use for discovery and interpretation. Many approaches for understanding science do not emphasize the iterative process as a "learning process" (Oppermann, 2013), rather it is presented as a tool to be used for data analysis.

Learning can take place in many forms and places. It happens planned and unplanned, controlled and uncontrolled, consciously and unconsciously, singularly and collectively (Oppermann, 2013), but no matter how learning occurs it must be completed with steps that build on each other to produce a deepened understanding of the idea. The steps form a cycle of processes that are continually modified and revised until and theory or law is established. Therefore, learning is an iterative phenomenon; it evolves step by step using early knowledge for later understanding (Oppermann, 2013). To achieve the highest level of learning a student must be able to perform this practice on their own, based on their own experiences. A student is less likely to forget the information they teach themselves or information that is taught to them by their peers. This could be due to the fact that a substantial part of learning does not happen during instruction but during task performances (Oppermann, 2013). Accordingly my students will come to understand the iterative process through multiples examples and applications from their own experiences and other real world applications.

Now that the significance of the iterative process is established, I feel it is important to explore the question of how and when the process can be applied. The first question, of how it can be applied, can be summarized in three steps that I will explain below.   These steps will ensure that the iterative practice is being used appropriately.

Initiating the process with one trial or experience will provide my students with rudimentary knowledge about errors, challenges, and solutions. However, one trial or experience is not sufficient for full understanding and which makes the person more likely to forget the key concepts. To avoid forgetfulness the experience has to be reinforced and extended by re-use in identical or similar situations (Oppermann, 2013). This produces skills that my students will be able to use throughout their lives. However, if the process is not done correctly the skills will be lost. It also helps them understand how revisions to initial preconceptions lay down the foundation for discovery, by strengthening your process skills.

Avoiding the loss of critical skills can be achieved by adhering to these three steps or learning stages (Oppermann, 2013):

1) **Cognitive Stage:** During this stage an individual learns about basic skills through instruction and observation
2) **Associative Stage:** During the stage an individual practices a skill until it becomes smooth and accurate
3) **Autonomous Stage:** In this stage an individual performs skill essentially without attention

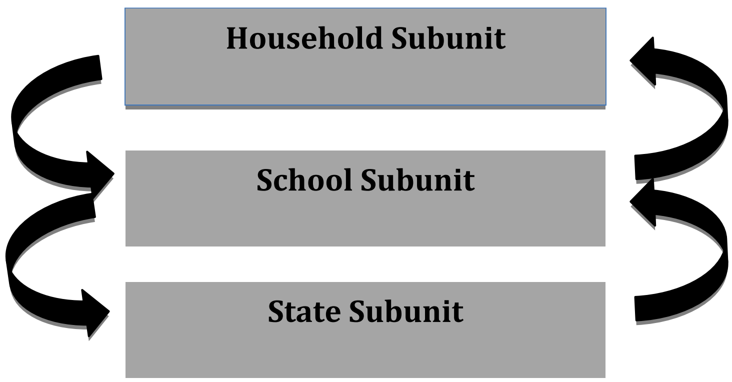
The Cognitive Stage would involve me directly instructing the students on foundations of the process. In my unit, this will include an introduction to the steps of the scientific method, the definition of each step, along with examples of how these steps look when executed. The Associative Stage will play out in the unit by having the students perform much practice of the skills learned in the cognitive stage. This will include multiple activities and investigations that build on each other with modifications to preexisting procedures. They related skills will be developed from what they learned in the cognitive stage. Students may then continue to execute experiments until they have completed the experiments at a proficient level. If students happen to achieve the concluding, autonomous stage, the student will be able to perform the skills like its second nature. For this unit, that may resemble students engaged in investigations without the facilitation of myself or any other teacher.

Students who reach this stage will have mastered the skills necessary to become proficient. I intend to use these stages to reinforce the skill of the using the iterative process. If achieved my students will have learned a skill that will be used throughout their lives.

Studies have shown that the role of iteration in qualitative data analysis, not as repetitive mechanical task, but as a reflexive process, is key to sparking insight and developing meaning. The meaning of reflexive is this context refers to cyclical nature of the process. The loop-like pattern begins with multiple rounds of revisiting the data as additional questions emerge. As that stage of the process unfolds, the identification of new connections begins to be unearthed. This should lead to more complex explanations, which guide the process of reflexivity. When these events develop they produce a deepened understanding of the material. Thus, fundamentally, it is an iterative process (Srivastava, 2013). Scientifically, this would provide you with the necessary tools to appropriately interpret the meanings of the data you have collected.

There are some scientists that believe that inductive analysis (the patterns, themes, and categories of analysis that come from the data, or emerge out of the data, rather than being imposed on prior to data collection and analysis) is the key to interpreting data. However, newer more progressive studies have shown that patterns do not emerge on their own, they are driven by what the inquirer wants to know and how the inquirer interprets what the data is telling him or her according to subscribed theoretical framework (Srivastava, 2013)… This makes the process more reflexive than objective when applying analytical procedures. If the process is continued, it should progressively lead to refined focus and understandings (Srivastava, 2013).

The effectiveness of the iterative process can be demonstrated in this real-world application diagramed below (Srivastava, 2013):

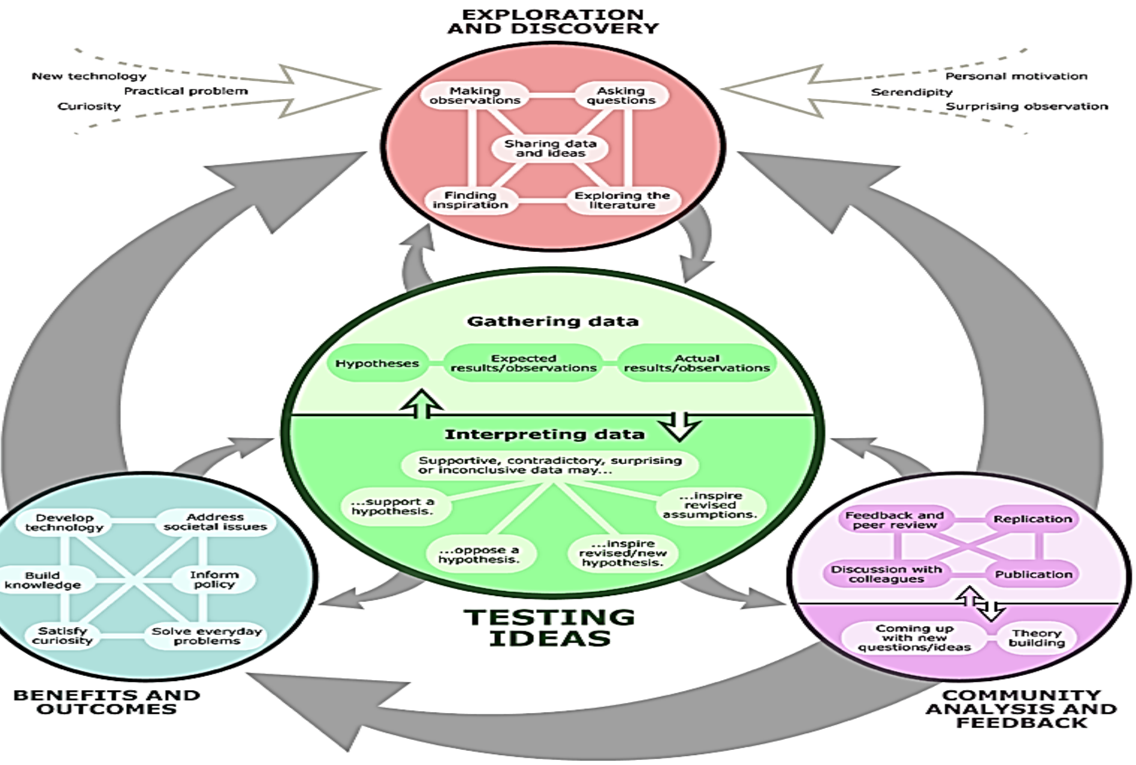


We can see from this model that each subunit depends on the next subunit to function. If one subunit were to be removed from the process, it could have dramatic impact on the effectiveness of the overall process. Again, we see the idea of something behaving as if it were irreducibly complex, depending on each of its parts to function.

In the example above, the households depend on the schools to educate their children; in turn the schools depend of the state to provide the resources the children need to be educated. Reversing the order of that process, we see that the state provides resources to the schools, which in turn educate their children, helping to improve the overall household.

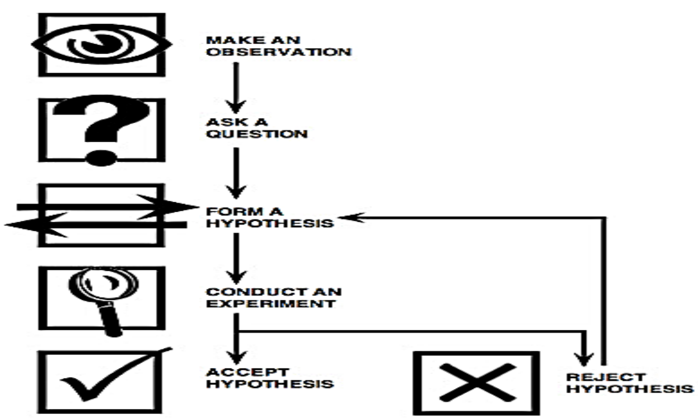
To truly make the process iterative and more efficient, modifications must be implemented. An example of a modification could be the type of resources that are provided. Theoretically, the iterative nature of this process would allow for the appropriate resource to be identified and utilized. This could be measured by the effectiveness of any of the subunits in the process. Understanding the many applications of the iterative process, like the example aforementioned, will increase my students understanding of the scientific process until they can achieve a level of mastery.

While the process demonstrates how the iterative can work in a real-world application, this model can easily be applied to the framework of the scientific process. The diagram below demonstrates the intricate cycles that are possible because of the iterative nature of the scientific process.



(Figure from http://undsci.berkeley.edu/article/0_0_0/howscienceworks_2)

After reviewing the diagram, the iterative nature of the scientific process should be evident. It should become clear, that there are many opportunities for iteration throughout the process. This provides the teacher with a great amount of versatility when establishing what lessons to use when teaching the material. For the purposes of the unit, I will focus on a more simplified version of this method, which can be expressed in the following model:



(Figure from http://static.ddmcdn.com/gif/scientific-method-17.jpg)

This more simplified version will be easier for my students to understand, helping them to relate all the different stages to each other. I also favor this version because it leaves open the opportunity for students to identify critical steps that may have been left out. By identifying critical steps that have been omitted, or steps that can be substituted, the students are increasing their understanding of the process.

Objectives

My objectives for this unit are focused on my students understanding the iterative nature of the scientific process by utilizing very useful practices of the process. For this to occur, a few goals must be met. First, my students must be able to provide a summary of the scientific process. Next, they must be able to relate the process to real world application. Thirdly, complete several activities that will reinforce the major ideas related to the iteration in the process. The activities will be built directly into their experiments, seamlessly integrating all the objectives of the unit. If all of the objectives can be met then the overarching theme of the unit will be achieved. Students will have will have developed a mastery of a critical concept in scientific inquiry. In addition, I will address some more broad and general objectives that align with the PA standards. Throughout this section of the unit, I will elaborate on how the state standards more specifically align with my own objectives. Listed below are the four state standards that will be addressed in this unit:

> 3.7.10.B: Apply appropriate instruments and apparatus to examine a variety of objects and processes.
> 3.2.12.C: Apply the elements of scientific inquiry to solve multi-step problem
> 3.2.10.B: Apply process knowledge and organize scientific and technological phenomena in varied ways.
> 3.2.12.B: Evaluate experimental information for appropriateness and adherence to relevant science processes.

PA Standard 3.7.10.B

This standard will align with my curriculum in a very direct way. This is because students will be constantly engaged in the use of testing instruments and equipment throughout the unit. They will use these resources to test for the different molecules that exist in foods. Examples of some typical resources we will use include: Indicator solutions, test tubes (or any container for testing), stirrers, gloves, etc.

In addition, these tools will be used to develop their skills with instruments that are used in science applications. The more practice and exposure my students receive the closer they will get towards achieving proficiency in science. The will become comfortable with the tools and begin to understand their significance to the iterative process.

PA Standard 3.2.12.C

Iteration is the overarching theme of the unit; therefore the unit gives a large amount of focus to highlighting the objectives of that theme. This standard will receive more attention than the others since it is the most closely related to my overarching theme.

Constant exposure to this theme is intended to produce a deep understanding that will be able to use in all their experiences with science.

All activities in the unit will use scaffolding techniques to reinforce many of the major concepts. This will teach my students the importance of using multi-step methods to solve problems. Each step will emphasize an essential skill necessary to master the scientific process. As they develop each skill they will become more and more proficient with the process. By the end of the unit, students should have a more robust understanding of the scientific process, particularly how the steps of the process form a never-ending cycle of inquiry.

PA Standard 3.2.10.B

During the unit, there will be several instances where students will collect data. The collection of this data will help support their hypotheses and conclusions they derive from each experiment. Relating the results to the hypotheses will help students see the significance of using data to support their ideas. After making that connection, my students will organize their conclusions to explain the observed results from their experiments. They should also recognize that, often results and conclusions lead to more questions reinforcing the iterative nature of science.

PA Standard 3.2.12.B

The experimental information collected in this experiment will also be used to confirm the significance the iterative process in science. Since, this is the overarching theme of the unit, relating the beginnings of experiments to the ends, and the ends to new beginnings, reinforce the theme giving students a deeper understanding of the process works. Again, I will reiterate (no pun intended), that the more my students are exposed to the nature of the process, the more comfortable they will become applying it in various ways. Accordingly, each one of the aforementioned objectives has many common attributes. By connecting all the objectives to the iterative process they will ensure they have developed an understanding they will be able apply in all facets of their life.

Strategies

There is a Chinese proverb that states, “I hear and I forget, I see and I remember, I do and I understand.” I believe this accurately summarizes my approach to this unit in many ways. The proverb suggests that, learning by doing, is an effective method that can be used for understanding. It also highlights the immediate need for a hands-on approach in science teaching (Huary, 2013). Studies have shown that without this approach students struggle when relying on rote memorization during state tests. When students must rely on memory and abstract thought, their creativity and learning become restricted (Huary, 2013). By actually doing and experiencing science, students develop critical thinking skills. Ultimately, avoiding these strategies can lead students to poor performances on state exams.

More specifically, I intend to use the hands-on approach for teaching since I feel it best demonstrates the iterative nature of scientific process. I selected this style because, in my experience, it's one of the best methods for learning, particularly in science. It is my belief that, teachers who embrace hands-on learning in science doing a better job of endorsing student-centered instructional approaches (Huary, 2013). Student-centered approaches give students responsibility and encourage them to be accountable for their work. In turn, accountability will help them sustain their motivation to learn science. Hands-on learning also helps to differentiate the lesson by presenting different methods of learning. This can be helpful with English Language Learning (ELL) students, students with auditory deficiencies, or behavioral interference, because the students become part of the process and not just spectators (Huary, 2013). Studies have shown that there are many more benefits to using hands-on learning, however to avoid being convoluted and explain them all, I have listed them below for reference (Huary, 2013):

- Increased Learning
- Increased Motivation to Learn
- Increased Enjoyment of Learning
- Increased Skill Proficiency, Including Communication Skills
- Increased Independent Thinking and Decision Making
- Increased Perception and Creativity

The format for this approach will play out very similar to a case study that addresses the specific question, "What is our food made of (molecularly)?" The more essential features included in unit, involve an investigation that was borrowed from my seminar leader, on starches and proteins. Information and procedures from this investigation can be found at http://serendip.brynmawr.edu/sci_edu/waldron/#starch. Specifically, activities 1 and 2 in my unit are derived from this resource. The notable features this resource presents include, taking on a question and working cooperatively to come up with a plausible answer, making hypotheses and then revising and modifying those hypotheses, and then using various scientific tools to analyze and interpret the collected data. My intention for this unit is to use the answers to the questions as inspiration for new questions, taking them in a new direction of experimentation. These methods should reinforce the iterative nature of the scientific process.

The hands-on approach to learning will be established throughout the entire unit. Multiple activities will encourage this style of learning until they have a proficient understanding of the iterative nature in science inquiry. According to Jean Piaget, the Swiss philosopher and psychiatrist, it should be mandated that the learning environment should be rich in physical experiences (Huary, 2013). His research and my own experience have both help lead me to the same conclusion.

One way in which the approach will be demonstrated is by having the students collaborate with each other to answer the same questions. If achieved, everyone is engaged in a similar set of experiences, so everyone can participate in discussions on a level playing field, regardless of their socio-economic status (Huary, 2013). This is of particular importance to my unit since my student demographic is very diverse.

Another way in which the approach can be utilized is by performing experiments on the questions that they raise. Performing experiments will engage students in multi-step processes used to answer questions. This causes students to rely on evidence instead of upon authority (Huary, 2013). Most students live in a world where most learning is conducted authoritatively; therefore it is refreshing for students when they are removed from that environment.

The last representation of the hands-on approach, stems from the research my students will complete as they perform their experiments. The research will assist them with completely understanding the purpose and relevance of the unit. It should also encourage new questioning because when students carry out their own experiments, they become very familiar with the events and variable involved. Coincidentally, this also promotes cause and effect thinking, which is an essential skill that can be used to understand how science is an iterative process.

In conclusion, the benefits of this approach seem to be more than sufficient justification for promoting hands-on learning. Besides helping students remember material better, feel a sense of accomplishment and be able to more easily transfer those experience to other learning situations (Huary, 2013), the approach makes science fun for both the student and teacher.

Classroom Activities

Activity 1
<u>Objectives</u>

By the end of this lesson students should understand how to apply elements of scientific inquiry to solve multi-step problems. They will also apply the appropriate instruments and apparatus to examine a variety of objects and processes. The processes will allow them to make initial hypotheses, collect data, and then analyze the results. They will then take the results and modify their hypotheses as necessary. They will begin to understand that some or all foods derive from animals, or some or all foods derive from plants, or some foods derive from both animals and plants. Completion of these objectives will bring my students closer to understanding how the process of science is iterative.

<u>Anticipatory Set</u>

Students will be introduced to the investigation for the day by drawing on previous background knowledge about organic and biochemical compounds. They will answer the prompt, "Explain how Biochemical compounds provide the foundation for life." After explaining their answers, students will share their answers and engage in a class discussion. Prior to this lesson, my students will have had instruction on the molecules and compounds that are found in the body along with how they make up the building blocks of life. This should provide a rich discussion on the significance of these compounds and what life would be like without them. Completing this part of the lesson should take from 5-7 minutes.

Direct Instruction

Following the anticipatory set, students will be introduced to the question that will guide them through the investigation. They will be told that the day's investigation focuses on the polymers, starch and proteins. They will then be asked to come up with questions about what they would want to know about starches and proteins and share them with the class. Before they begin their investigation, we will review what a starch and protein are and why they're essential for life. This should help them come up with a variety of questions that will guide their investigation, such as, "Which types of foods contain starch and what types of foods contain proteins?" If they cannot come up these questions on their own, it will be provided for them. They will then group together and develop hypotheses about which foods contain these polymers along with an explanation as to why they think so. After a brief discussion of their hypotheses, students will be given another question, such as, " What types of ways can we test for these polymers?" Once they have developed their own procedures, they will share them with the class. Then, as a class, we will decide what the actual procedures will be for everyone to follow. Following a discussion of this question, we will engage ourselves in the investigation. This part of the lesson should last approximately 15 min.

Guided Practice

The next part of the lesson will have the students use the supplies given to complete the investigation. I will model, for the students, how to complete the essential steps of the procedure. In addition, students will assign a specific role to each member of their group, whether it be a scribe, presenter, or doer of the experiment. With each member having a role, they will proceed with the completion of the investigation. This section should last approximately 5 minutes.

Independent Practice

My students will use a handout with the investigation procedures to complete the investigation. The procedures, along with other important information about the investigation, can be found in the following website, http://serendip.brynmawr.edu/sci_edu/waldron/#starch. In that information, you will find detailed instructions about what indicators are used and when to use them, what samples will be utilized, along with the instructions for how to execute the procedures for the investigation. Next, I will assign each group a specific task and they will proceed to record the results of the investigation. This step of the lesson should last for 20 minutes.

Closing

To conclude the lesson students will share their results with the class and discuss the implications. Each student will then revise their original hypothesis based in the results of their investigation. After each student makes their modifications, I will check to make sure their hypotheses are relevant to investigation. Then we will discuss how the new hypotheses will serve as the starting point for the next day's lesson. The closing of the lesson should take no longer than 5 minutes.

Homework

Students will complete follow up questions on the investigation for homework. The questions will involve understanding the purpose of the investigation and what types of new questions we can use to build on what we learned from the completed investigation. They will bring the answers to these questions in class the next day and review how their conclusions correlate with the iterative nature of the scientific process. They will also use the information begin their next investigation of what is in our food.

Activity 2
Objectives

Students will build on their previous investigations by applying what they learned to the activity of the day. This will help reinforce the skills they need to master in order to understand the iterative nature of science. They will also use appropriate instruments and techniques to measure and collect data in the investigation increasing their mastery of the scientific process. By the end, students will be able to identify and differentiate between the foods that contain starches and proteins. The concepts from this lesson will continue to increase their mastery of the scientific process.

Anticipatory Set

Students will begin class by exploring their hypotheses regarding which foods contain the polymers starch and proteins. After reviewing their hypotheses, students will share them with the class and we will discuss the strengths and weaknesses of the arguments. During this time we will discuss how reasonable each hypotheses is and how the proposed hypotheses can be tested.

Direct Instruction

During this stage of the lesson students will be asked to hypothesize the answers to three specific questions, which include hypothesis about, *which types of foods contain starch, which types of foods contain proteins, and to predict the content results of certain foods (ex. Beans, Butter, Jelly, Bread, and Yogurt).* When they have achieved a full understanding of the material, they will move on with their hypotheses and followed by a discussion of the hypotheses with their nearby peers.

Guided Instruction

Next we will collectively come up with the proper testing to help us identify the appropriate testing to be used for our hypotheses. To do so, I will guide them the possible testing options that are realistic for us to complete. After a review of our possible testing options, we will decide as a class which option is best for us and then organize the procedures to suit our needs.

Direct Instruction

Once the class has decided on a way to test our hypotheses, each test will be assigned to a specific group. Each group will then test their given hypothesis and collect data based on the results of the test. As the students complete their test and collect their data they will answer questions that coincide with the procedures in the investigation. After the students complete the investigation and questions they will discuss their answers with their nearby peers.

Closing

To close the class, students will be asked to assess the results from the investigation and modify or revise their initial hypotheses made in the beginning of the class. To exit the classroom they will be responsible for summarizing their revisions on a notecard.

Homework

Students will review the question I asked to close the class and identify how they could test their new hypotheses. Their new hypotheses and test will be used as a starting point for the next lesson.

Activity 3
Objectives

Today's activity will be a follow-up to yesterday's investigation. By the end of the today's lesson students should gain a better understanding of the iterative nature of science. They will accomplish this by modifying and revisiting hypotheses they created in the previous investigation. The new hypotheses or questions they will develop will be tested and analyzed again. This will assist them in understanding the proper procedures necessary to implement the iterative practices in the scientific process. My students will also be able to apply appropriate instruments and techniques to the investigation, which should increase their mastery of the subject.

Anticipatory Set

Students will be asked to explain their new hypothesis or new questions and identify how they expect to test it. Following their completion of the question, they will share their answers with the class as we discuss the strengths and weaknesses of many of the new hypotheses. It will be made clear that their new hypotheses should be a modification or revision of their old hypotheses based on the results of the previous investigation. Once that is identified, they will relate their own experience with the iterative practices that fuel the scientific process.

Direct Instruction

At this point, students should have recognized that, while they may have new hypotheses or questions, the procedure they will use to test their new purpose could be tested in very much the same way depending on the purpose identified.   However, some of them are more than likely to come up with questions that may be out of your capabilities to test. Some questions may include, "Why do our bodies need starch and protein? Or how come some foods test for both starch and proteins?" When this becomes the case, students should explore their purposes using the any resources available. They will be told that sometimes a known testable procedure for a hypothesis or question might not be available. When this occurs, a person must develop their own ways of testing their theories. Furthermore, to address this challenge, my students will use the Internet to explore and identify additional resources to help them design their new procedures.

Guided Instruction

In this phase of the lesson, students will be guided through the development of the procedure to test a theory. To begin, we will review the 6 critical steps of the scientific method along with the significance of each step. Following that, they discuss with students sitting near them, their hypotheses about how to conduct a test for their hypotheses/questions. After their discussion with each other, they will use the Internet to explore and record potential answers to their questions.

Independent Practice

During this phase of the lesson, students will collect information from Internet regarding their newfound purposes. In addition, they will use that information to develop the procedures to test their theories. While they develop a procedure that can be tested, they will remember to include the scientific method format that is widely used throughout science curriculums around the country. That being the guiding structure of the of discovery, which includes starting with a purpose, performing research, creating a hypothesis, testing that hypothesis, collecting the data, analyzing it, and finishing with a conclusive summary. Their procedures will reflect a similar structure when developed.

Closing

To end the class, students will be asked to reflect on the day's lesson. They will be asked to explain how their procedures reflect the iterative nature of the scientific process. Included in their explanations should be examples that highlight opportunities for revisions and modifications to be made and then tested reinforcing the cyclical essence of the scientific process.

Homework

Students will be expected answer with an explanation the following question for homework, "Explain how starches and proteins are used by the body." Their explanation of the way our bodies interact with starches and proteins will serve as the starting point for the next day's lesson.

Annotated Bibliography

1) A Practical Iterative Framework for Qualitative Data Analysis: International Journal of Qualitative Methods; International Institute For Qualitative Methodology. Prachi Srivastava, University of Ottawa. Nick Hopwood, University of Oxford, 2009.
This source was utilized to provide evidence for the argument of this unit, which explains how it is critical to understand the iterative nature of science. The source supports the argument by providing examples of how analyzing information can be done more efficiently when using iterative practices. The source is considered reliable because it originates from two of the more prestigious universities in the world.

2) Learning and Problem Solving as an Iterative Process: Learners' Living Repository: LEAR. Richard Oppermann, Christoph G Thomas. German National Research Center for information Technology, Sankt Augustin, Germany, 2013.
This source facilitates the argument of this unit even further by explaining the versatility of the iterative process. Its versatility is implied with the many examples the source provides. The examples highlight how critical the skill of problem solving is in our world. Furthermore, if a person can master this skill, they can implement throughout many facets of their life, including education, but particularly in science. This further justifies and makes clearer the theme of this unit. This source is substantiated by the fact that it was published in Germany, by an institute founded by the government.

3) Physical Science Magazine: "What are the benefits of hands-on learning? How do I justify a hands-on approach?". David L Huary, Peter Rilero. Journal of Science Teacher Education. April 24, 2013.
This source supports the overarching theme of the unit, by explaining the benefits of using hands-on learning. Specifically the passage focuses on just how essential hands-on learning is for science. The article makes its point using support from the early education philosophers who also favored the hands-on approach style of learning. It continues its argument by providing examples of the different ways the hands-on approach can be utilized in a scientific setting. I consider this source to be reliable because it was published by a well-established science magazine by accomplished science educators.

4) "The Real Process of Science". University of California Museum of Paleontology. 17 March, 2013.
<http://undsci.berkeley.edu/article/0_0_0/howscienceworks_02>
This source serves as the basis of my argument for the unit. It explains how the nature of the scientific process is iterative. It does so by providing examples of multiple steps can be revisited or revised to produce new insights. It then

highlights how the recycling of many of the practices reinforces the iterative nature of the process. I consider this to be a reliable resource because the website and the information provided was designed by the University of California Museum of Paleontology.

5) Starch and Protein Investigation. University of Pennsylvania, Biology Department. Dr. Ingrid Waldron, Dr. Jennifer Doherty. November 2012. <http://serendip.brynmawr.edu/sci_edu/waldron/#starch>
This source was of great use to me because it provided the basis for all the activities in the unit. The investigation highlights the iterative nature of science by constantly revisiting and revising integral concepts of the investigation. The source reinforces the important nature of science by having the students practice specific skills repeatedly. This source is a reliable resource because it was developed by experienced, well established University of Pennsylvania professors.

Appendix/Content Standards

Content Standards

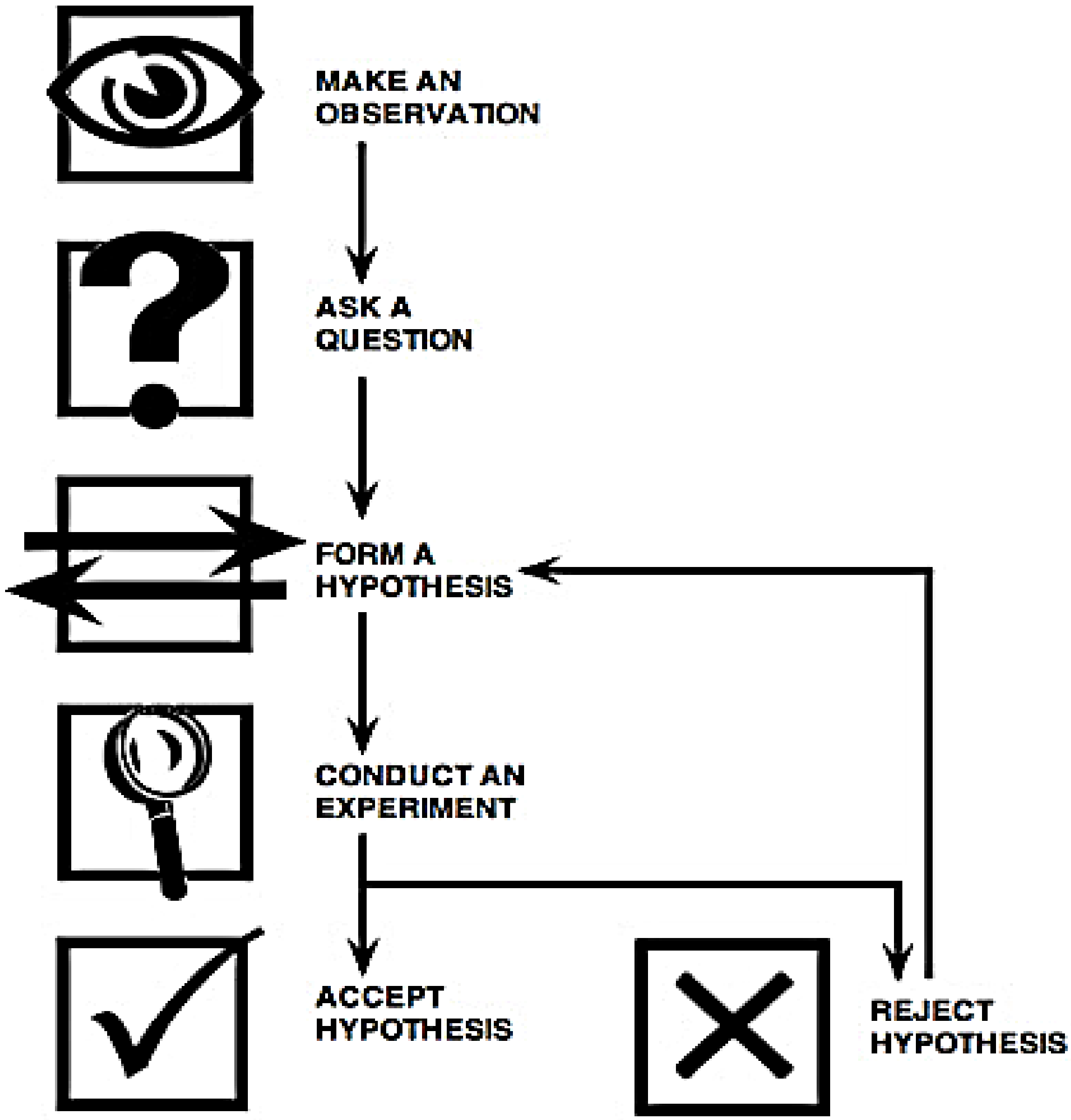
3.7.10.B: Apply appropriate instruments and apparatus to examine a variety of objects and processes.

3.2.12.C: Apply the elements of scientific inquiry to solve multi-step problem

3.2.10.B: Apply process knowledge and organize scientific and technological phenomena in varied ways.

3.2.12.B: Evaluate experimental information for appropriateness and adherence to relevant science processes.

Scientific Process Model 1



Scientific Process Model 2