**Slime and Other Adventures:
Inquiry-Based, Hands-on Learning**

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INTRODUCTION

Even now, many years later, I still vividly remember my first science fair project from middle school. I chose to study crystals because it seemed like fun. I associated crystals with the beautifully shaped sugar crystal “rock” candy that we got on special occasions. I always loved their perfect shape and clean lines. I have always been so amazed at how crystals form with such sparkling design. Each candy was so similar in shape, yet unique in its own way.

I still have the book my mother bought me on crystals to help with my research. My mother bought the book before nonfiction for young readers was readily available. The language was very complex, but it served its purpose. I can also remember designing my experiment and gathering materials and recycling containers to use. I remember the excitement of watching the solutions for progress and writing in my log each day. I can recall the feeling of confidence as I prepared my project for delivery to school, writing up my conclusions based on information I had collected. It’s a memory that is still with me today.

As a teacher reflecting on my science project, I see that I was developing the process skills needed to continue in science with confidence. These process skills included questioning, observing, measuring, evaluating and investigating - all necessary skills for inquiry. The best part of the project was the feeling I got from actually doing the project. I felt a true sense of ownership over my project. I picked the topic, came up with the question and hypothesis, designed the experiment, and eagerly charted the progress by keeping a log and measuring the crystals’ growth. I drew my own conclusions and remember being nervous that my results weren’t quite what I had expected. But I remembered that my teacher had explained that things don’t always work out as you expect. So I interpreted the data I had collected as best as I could. I prepared my display board neatly and carefully. I took such pride in it because it was mine. I was engaged and enthusiastic because it was my project.

When I continued on in the science fair, I was incredibly nervous. I didn’t care much for competition. For me, the best part was truly doing the project. I felt proud, independent and confident in my ability to “do science” and to be a scientist. Everyone can be a scientist.

I feel lucky that I had teachers who were passionate about science and promoted student learning through inquiry. I remember them distinctly because they encouraged the scientist inside of me. This experience was an example of the inquiry-based learning that I advocate. This is what I want to share with my students because I have experienced it myself and I know it to be an enjoyable and interesting way to learn.

Young children are naturally inquisitive. They want to know what things are made of, what they do, and how they react with each other. Children want to know how things work. The most natural way for children to learn how something works is to try it out for themselves. This incredible source of intrinsic motivation for learning can be stifled with memorization and rote practice, or it can be encouraged with inquiry learning and hands-on experiences. Many students make stronger and longer lasting connections with concepts when they deal with them in a concrete manner. An even stronger connection can be made when these concrete, hands-on explorations are based on student interest and input. This allows children to make a personal and meaningful connection to the content of any subject.

Many students do not experience science in a way that is either interesting or meaningful to them. Many students start learning science from a textbook, even as early as first grade. When my first grade students come to school at the beginning of the year, they are excited about school, generally eager to participate and curious about new things. If these naturally inquisitive students are given a textbook and worksheets to do, and are told that they are doing science, it would hardly leave them wanting to do more. However, if these naturally inquisitive students are instead given an opportunity to truly explore concepts, to interact with content through inquiry-based learning and hands-on experiences, then they can retain their natural inquisitiveness and develop a sense of excitement when its time for science. It is important that students feel this way about science in each grade as they progress through school. Further, inquiry-based learning and hands-on experiences are beneficial teaching strategies in all content areas.

UNIT GOALS

This unit will focus on the nature of science and the process skills through inquiry- based learning and hands-on experiences using polymers. Polymers are a class of materials in chemistry that have some intriguing properties that you can really get your hands into. The unit is planned to take a month but it can be expanded depending on student interest. The unit has been created with lower elementary students in mind, but it can be adapted for students in higher grades as well. Students in the lower elementary grades in particular, need to build a science foundation based on the process skills and scientific inquiry. It is important to build a foundation based on these things because it provides children with the skills to approach any area of science.

This unit will teach them to ask questions, plan and conduct investigations, make observations, measure, record, compare information, draw conclusions and communicate what they have learned. These are expectations found in the National Science Education Standards (NRC, 1996) and the American Association for the Advancement of Science's Benchmarks for Science Literacy (AAAS, 1993). The students will develop these skills through inquiry-based learning and hands-on exploration. It will be an opportunity for students to discover, explore and play with ideas.

In our culture of video games and instant gratification, this is a valuable opportunity to draw students in with an exciting and fun set of projects while developing critical thinking skills and an appreciation for the process of inquiry. It is important that children be familiar and comfortable with exploration, investigation and inquiry, as they are our future scientists. There is an incredible amount of potential waiting to be unlocked.

OVERVIEW OF POLYMERS

Why use polymers?

Polymers are an incredibly fun way to introduce students to the nature of science, chemistry and inquiry-based learning in a real and meaningful way. Polymers are all around us. They occur in nature as well as in the manufactured products that we use every day. Some examples of polymers include hair, DNA, nylon and glass. Plastics are also examples of polymers. Plastics are an important part of our society and have many uses. "The development of plastic today involves the combination of many repeating groups of chemical elements such as oxygen, hydrogen, nitrogen, carbon, and other organic and inorganic elements as well. A unique combination of atoms and molecules of these elements in a single link, along with heat and pressure, will fuse the atoms together, thereby producing a long chain (polymer) that forms a plastic material with different mechanical and physical properties" (Ndahi 18). Plastics are created in different ways to create products that have different properties. Polyethylene, polystyrene and polypropylene are examples of plastics. Mebane and Rybolt's book, *Plastics and Polymers*, provides a number of activities with polyethylene that could be utilized for inquiry-based learning experiences.

There are a number of slimes that are polymer based. Students are fascinated by slime and awed by its unique properties. They love getting their hands "messy" while making and experimenting with different polymers. Further, there are lots of fun, interesting and easy inquiry-based activities students can do using polymers. But, you don't have to use polymers to teach science this way. You could choose any part of the science curriculum. Still, polymers serve as a basis for good science instruction. But more importantly, they are just plain fun!

What do you as a teacher need to know about polymers in order to teach this content to your students?

Although polymer chemistry is highly complex, the underlying concept can be understood in basic terms. As with student learning, I find it easiest to understand a concept when I am able to engage in hands-on experiences. I think that you will also find that polymers and their properties are much easier to understand when you have some slimy polymers in your hands.

So what are polymers?

Brian Rohrig gives the following explanation in his book *Pure Slime*:

> A polymer is composed of giant chains of molecules composed of repeating units known as monomers. The prefix *poly-* means many. In some polymers, such as polyethylene, the monomers are all identical. In others, such as proteins, the monomers may vary. A single polymer molecule may be composed of hundreds of thousands of monomers bonded together. Polymers may be natural – such as starch, protein, cellulose, and rubber. Or they may synthetic – such as plastic, nylon, and Silly Putty®. (15)

In order to understand polymers we need to know what monomers are. Monomers are the molecular repeating units that are chemically connected to each other to make an extended polymer chain. Polymers are long chains of monomers. For example, in the polymer polyethylene, the plastic polymer used in plastic grocery bags, the repeating unit is $-CH_2-CH_2-$. The monomer is $CH_2=CH_2$. Polymerization is the process where the monomers are connected to each other to form polymers. The Polymer Ambassadors' website recommends using paper links or paper clip chains to visually represent the repeating monomers that the form long polymer molecules (Polymer Ambassadors, 1996).

There are two common kinds of polymerization, addition polymerization and condensation polymerization. In addition polymerization, the monomers are added to one another, and all of the atoms from the monomers are used. The monomers in addition polymerization have carbon-to-carbon double bonds. The addition polymerization reaction is usually started with an initiator, which is a material that can produce a free radical. The free radical is an atom that has an unpaired electron, which is unstable and makes it reactive. The unpaired electron connects with an electron from the carbon-to-carbon double bond, also creating another free radical in the process. This free radical reacts with another carbon-to-carbon double bond, creating another free radical and the process continues. The process ends when the monomers run out or the free radical is not produced. Addition polymers are also called chain growth polymers. In the process of condensation polymerization, the polymer is produced from monomers but some part of the monomer is left out of the process.

In addition to slime, there are other polymers that can be used in hands-on, inquiry-based investigation. You may wish to investigate water-loving (hydrophilic) polymers. These polymers can absorb large amounts of water and are fun to play with. Some examples are cross-linked polyacrylamide copolymer gel and sodium polyacrylate. You can also investigate polymers that don't like water (hydrophobic polymers) or explore grow creatures that are combinations of hydrophobic and hydrophilic polymers. There are interesting inquiry activities that can be done with polyethylene. Students may be interested in investigating the properties of polymers including hardness, rigidity, flexibility and elasticity. In particular the property of density serves as the basis for a higher-level inquiry activity. Students can perform hands-on exploration of the differences between high-density polyethylene (HDPE) and low-density polyethylene (LDPE) plastics. High-density polyethylene is less flexible and low-density polyethylene is a more flexible plastic. Please note that this list is not intended to be complete and resources are listed if you are in search of a specific type of polymer or more technical knowledge. All of these materials can be used in hands-on exploration and the inquiry piece will depend on the direction of the teacher and/or students.

Slime

There are many kinds of polymer slime that you can make. The Elmer's® glue and borax slime is easy to make and the materials are easy to gather and use. Borax is sold under the brand 20 Mule Team® and is a multi-purpose household cleaner. Elmer's® glue contains the polymer polyvinyl acetate. Polyvinyl acetate is used in adhesives and paints. The polymer polyvinyl acetate $[-CH(COOCH_3)-CH_2-]n$ is produced through addition polymerization of the monomer vinyl acetate ($CH_2=CH-COOCH_3$). Brian Rohrig does a great job of explaining what happens when the polymer polyvinyl acetate in glue cross-links with the borax solution in his book *Pure Slime*. The polyvinyl acetate polymers in the glue are like long strands or chains that can move easily past each other. The addition of water, as indicated in the lesson plans that follow, makes the solution more fluid. When the borax, sodium tetraborate decahydrate ($Na_2BO_4 \bullet 10\ H_2O$), is dissolved in water, borate ions ($B(OH_4-)$) are formed. These ions link together the long polymer molecules of the polyvinyl acetate, making the slime form. This chemical reaction is called cross-linking. In this process, each time there is a cross-link, two acetic acid molecules are lost. As the ions are connecting the polyvinyl acetate chains together, a firmer substance is formed. The more cross-links there are, the more solid the substance becomes. The slime has properties of both a liquid and a solid making it really fun to investigate. You can actually feel the solution becoming more viscous as the cross links form because it gets harder to stir the solution. Making this slime after reading about it really helps you visualize what is happening when you make the slime.

Another great slime can be made with polyvinyl alcohol (PVA). Polyvinyl alcohol is a synthetic, water-soluble polymer. It is used in adhesives, films, elastomers and in making slime. Elastomers are a kind of polymer that has rubber-like properties. Polyvinyl alcohol is produced through addition polymerization using the repeating unit vinyl alcohol ($-CH_2-CHOH$). To make PVA slime you will need a 4% solution of polyvinyl alcohol and a 4% saturated solution of sodium tetraborate (borax). Both of these solutions can be made from the powder form or purchased as a solution from science materials vendors. In this chemical reaction the borax and water produces a tetrahedral borate ion that cross-links with the polyvinyl alcohol. This makes a really neat slime. This slime has slightly different properties than glue slime. One visual difference is in the coloration. The glue slime uses white glue and is opaque while the PVA slime is translucent. Students may want to add food coloring to the glue or PVA slime. This works best when the food coloring is added directly to the glue or PVA prior to combining it with the borax solution. Students may also want to compare and contrast the two slimes and practice making observations. They may be interested in inquiry activities comparing what happens when they are stretched slowly or quickly, or perhaps how well they bounce.

There are a number of great resources out there for making slime. There are other types of slime that can be made with different ingredients including cornstarch and packing peanuts. The list of slime possibilities is endless!

UNIT IMPLEMENTATION

This unit will be taught using an interdisciplinary theme and best known teaching practices, particularly inquiry-based learning and hands-on exploration. Integrating a unit on polymers or any science content, into the different areas of the curriculum allows for repeated and systematic interaction with "doing science. This unit will provide students with opportunities to interact with the material using visual, oral, auditory, and kinesthetic modalities in an effort to reach all students in the way that they learn best. In addition, this unit will teach students to think critically by teaching them the inquiry process. It will include direct experiences designed to teach students the science process skills necessary for true inquiry.

Inquiry-Based Learning

Children are naturally curious and inquisitive about the world around them. When they are interested in something, they have lots of questions. They are also intrinsically motivated to pursue the answers to those questions. When students are creating the questions and pursuing the answers, they have ownership over their learning and are invested in a successful outcome. As teachers we need to capitalize on our students' natural inquisitiveness and involve them in inquiry. As reflected in the National Research Council's National Science Education Standards (1996) and the American Association for the Advancement of Science's Benchmarks for Science Literacy (1993), these qualities in younger students represent the basis for excellent educational opportunities (Colburn 64).

There are a number of different versions of inquiry learning but they all include similar concepts. Inquiry is a process used to explore content areas. It is very similar to the scientific method but is more fluid and involves students in the process. The National Science Foundation maintains that children who engage in inquiry learning enjoy more opportunities to raise relevant questions and come up with creative answers to those questions through original planning, design and investigation (Dyasi). Further, the National Science Foundation states that inquiry learning gives students "ample time to reflect, engage in dialogue to develop their conceptual ideas, and defend their findings to others" (Rankin).

Inquiry is a constructivist teaching strategy. Constructivist teaching is based on the idea that learning is a process during which we construct our knowledge based on prior knowledge. It uses strategies that engage students by involving them in the learning process. Through the process of investigation, it teaches students about the nature of science and the process skills needed for scientific investigation. It also teaches them how to think critically and independently.

If you are wondering whether or not first graders can really participate in inquiry, the answer is unequivocally yes. We should be teaching our students inquiry. Most of the differences between different descriptions of inquiry-based learning have to do with the amount of student and/or teacher involvement in the inquiry process. According to Colburn, there are three distinct types of inquiry-based instruction. These include: 1) structured inquiry, 2) guided inquiry, and 3) open inquiry (Colburn 64). Essentially these divisions are based on who has the decision-making responsibility. As one moves from structured inquiry to open inquiry the responsibility shifts more to the students. I think this can best be utilized in a first grade classroom by starting with structured inquiry and progressing to guided inquiry, where the ultimate goal is open inquiry. I see guided inquiry as scaffolding. Scaffolding is providing support for student learning, moving gradually from teacher modeling of skills to independent skill development.

With inquiry-based learning I think that teacher modeling of the process with student involvement is the first step at any early age. As the year progresses, student responsibility should increase. For example, in the beginning the teacher may have already decided what is to be investigated and how it will be done. The outcome of the investigation is predetermined and the activity serves as an opportunity to model the inquiry process for students. This is a valuable interaction not only for the modeling of the process but also as an opportunity for students to practice process skills. As students become more familiar with the inquiry process the teacher should allow the students to have increased ownership of their learning and allow them to decide more of the direction of the inquiry.

Hands-on Exploration

Hands-on exploration is a vital component of science instruction for all levels of learners. What is hands-on exploration? Hand-on exploration is allowing students to explore science concepts first hand by actively participating in science activities. Students should be active participants in science activities and inquiry instead of simply observing demonstrations done by teachers, listening to teacher lecture or reading textbooks.

Hands-on exploration includes allowing students to explore concepts and materials using their five senses. Hands-on exploration allows students to practice the science process skills and develop observation skills. It lets students use materials and tools to investigate their predictions and to pursue alternative explanations for outcomes. Hands-on exploration is engaging and student centered. When students are engaged they are more interested and involved in their learning and are more apt to remember the concepts they are learning about. In your classroom it might involve allowing students to experience the difference between a push or a pull, weighing various objects, sorting real life objects by states of matter, or feeling the chemical reaction that takes place when making slime. It could even be planting and tending a garden or sorting vegetables by parts of the plant (leaf, root, and stem). The possibilities are endless and are only limited by the enthusiasm of the teacher and the motivation of the students.

Why is hands-on exploration important to utilize in science instruction? In many areas of learning, including science and math, concepts are often abstract. In order for students to truly understand a concept, it is necessary to understand the concept on a concrete level before it can be understood as an abstract concept. James W. Heddens in his article "Bridging the Gap between the Concrete and the Abstract," states that learners should be introduced to concepts at the concrete level and then progress along a continuum of learning, including semi-concrete and semiabstract levels, until they arrive at an abstract understanding. According to Heddens the semi-concrete level uses pictures of manipulatives instead of the materials themselves. Then continuing along the continuum, the semiabstract level uses symbols that do not look like the objects they represent. Although Heddens discusses this continuum of learning in the context of mathematical teaching and learning, I believe that it parallels teaching and learning in science. In order for students to students to understand scientific concepts and phenomena, it is important that they are able to experience it themselves and to interact with it (14).

According to Keith G. Diem in his article "Turn Any Science Topic into Hands-on Fun," students typically remember 90% of what they see, hear, discuss, and practice as opposed to remembering only 20% of what they read and 50% of what they see and hear (46). With statistics like this it is easy to see why it is so important that students have the opportunity to participate in hands-on exploration so that they can see, hear, discuss and practice what they are learning. The National Science Teachers Association's Position Statement on Laboratory Science states that a "minimum of 60 percent of the science instruction time should be devoted to hands-on activities, the type of activities where children are manipulating, observing, exploring, and thinking about science using concrete materials" (NSTA). When students are active participants in their learning they are more motivated and involved in the learning process. They are invested in their own success. The important concept here is that students must progress from the concrete to the abstract in order for meaningful and memorable learning to take place.

Hands-on exploration is complementary to inquiry-based learning. Students should be doing hands-on exploration as part of their inquiry-based learning. Whether the inquiry is more teacher directed or student led, students should be using hands-on exploration to create questions, investigate predictions, and solve problems. In addition, hands-on exploration and cooperative learning partner very well with inquiry-based learning. Students can work cooperatively as a team to explore concepts and questions that they encounter through the process of inquiry.

Inter-Disciplinary Unit Connections

This curriculum unit focuses on instilling excitement and positive interactions in science using inquiry-based learning and hands-on exploration, with a focus on polymer chemistry. The unit will involve the areas of science, math, social studies, reading, and writing. In science we will use inquiry-based learning and hands-on exploration to investigate polymers, their actions and properties. The lesson plans that follow this section focus on inquiry-based, hands-on lessons using slime. Throughout the unit a number of investigations should be conducted using different polymers. These polymers may include hydrophilic and hydrophobic polymers, plastics, and rubber. In addition, any area of science could be substituted for the content. It is the strategy and teaching methods that work together to develop a positive attitude towards science. Using multiple teaching strategies is important because it keeps students interested and increases student achievement. These activities will allow students to use grade level appropriate lab equipment and materials. In addition to using these tools, it will help to develop the students' content area vocabulary. It is my experience that students learn best when they are invested in their learning. The activities should be designed to allow for student input and decision making in order to make the students' learning meaningful. The lesson plans that follow start with more teacher-directed inquiry and progress to more student-directed activity. As students become more familiar with doing inquiry, they will be able to work more independently. The teacher will need to gauge the direction of the inquiry based on student interest and independence. The lesson plans that are included provide a series of three lessons that can be used with any polymer. The specific activities to be done will depend on the interests of the students and teacher as well as the materials that are available.

Throughout the unit students should have multiple opportunities to develop the science process skills using hands-on exploration. They will observe, classify, make predictions, experiment, collect and analyze data and make conclusions based on what they have learned. In this unit students make slime following different recipes and with different ingredients. They should make these slimes themselves and observe them, especially making use of the sense of touch. Students should not only observe the slime but also should observe how it acts and explore its properties. Students should participate in classifying the slime according to its properties. Hands-on exploration of the slime should be an integral part of classifying these substances. Students should also participate in hands-on experiments. In the lessons that follow students participate in a hands-on activity that illustrates what happens when everyone does not follow the same instructions. Inquiry activities should involve hands-on exploration. For example, students may be interested in investigating how fast different kinds of slime slide down a slope. Although there are different levels of independence that the teacher can allow the students to have, all of the activities should involve students doing hands-on exploration of the slime and its properties. In all of the activities included in the unit, the students will reflect on their observations and the differences in the results to make conclusions about the polymers based on evidence. There is an important social aspect to inquiry that will also be addressed in this unit. The activities will require cooperative group work and critical thinking skills. While it is important that students can explain what they have learned in words, writing or pictures, it is also important that they communicate with each other during the inquiry process.

> An inquiry classroom relies on open communication. For the students, that means talking to others, listening to their evidence and explanations, and representing their own results in a clear manner…It implies that socially gathered and shared information informs individual learning. (Ash)

The students will keep science journals where they will write about their observations, calculations, predictions and results. They will keep track of mathematical measurements and calculations. During each hands-on exploration students should develop their measurement skills. Through the series of lessons plans provided the students should develop an understanding of the importance of accurate measurement. Students should be familiar with both standard and metric measurement. This will also help to develop their science vocabulary. This vocabulary may include general concepts such as more and less but should also include words for tools and specific concepts. Students will collect data from their inquiry and use the data to create tables, graphs and charts as appropriate. They will also illustrate their observations and investigations, including labels to diagram their work.

The unit also integrates social studies and reading. Grade level appropriate content area books will be provided for students to access during independent reading. The teacher will read aloud stories of chemists who invented and developed polymers. We will utilize these stories to discuss "Eureka Intuition" and serendipitous discoveries and look for scientific creativity and ingenuity. Eureka Intuition is the discovery of something that happens by chance. Serendipitous discoveries are discoveries of things people weren't looking for initially. The topic of inventions and children as inventors fits in well here. Natural inquisitiveness, curiosity and the desire to create seem to be innate in children. Recently I asked one of my first grade students what topic he would like to do some independent reading on. He wanted to think about his research topic so I checked back with him towards the end of the day. I was surprised and intrigued by his answer: inventions. When I asked him why he chose inventions, he responded that he liked to make things out of the things that he had at his house. Here is an opportunity to develop scientific inquiring minds of the future.

In conclusion, this unit utilizes polymer chemistry to engage and stimulate children's interest in science through hands-on exploration, and give them a vested interest in their own learning through inquiry-based activities. This unit and the lessons focus on inquiry-based learning and hands-on exploration of polymer slimes. Slime is a wonderfully curious substance that borders the line between solid and liquid. It provides opportunities to explore science concepts, develop science process skills, do cooperative group work and develop critical thinking skills.

LESSON PLANS

Lesson One

Lesson Objective

The objective of this lesson is to teach students to use inquiry-based learning to understand why different variations of this slime are formed when specific procedures are not followed. The goal for students is to analyze why different outcomes are reached when only general (nonspecific), directions are followed.

Materials

1 pair of goggles per student
2 clear plastic cups for each student
1 craft stick per student
1 bottle of Elmer's® white glue per student or pair of students

1 container of room temperature water per small group of 3 – 4 students
½ cup of 20 Mule Team Borax®
1 liter of hot water
1 2 liter container with lid
1 bottle of liquid food coloring for each small group of 3 – 4 students
1 paper plate per student
1 plastic zip-lock baggie per student
Assorted measuring cups and spoons per small group
10 paper towels per small group for clean up
1 sponge for teacher use
Chalkboard or chart paper
Chalk or marker for teacher
1 pencil for each student
1 science journal for each student

Introduction

Students will be encouraged to be independent in the creation of this slime. The teacher's role is to guide the students with general directions, write down student observations and facilitate the development of ideas. Be sure to gather all materials ahead of time. Each small group should have bottles of glue, containers of room temperature water, food coloring, assorted measuring cups and spoons, and paper towels.

Safety

Students should be supervised at all times. This slime is not to be eaten. The students and teacher should wear safety goggles when working with these materials. Borax should be kept out of the reach of children. Avoid contact with eyes and do not take internally. Read the caution and directions on the box prior to using.

Procedure

1. The teacher will need to prepare a 4% borax solution just before the lesson. The solution can be made by mixing a ½ cup of 20 Mule Team Borax® and 1 liter of hot water in a 2 liter container. Put the lid on and shake until the borax goes into solution.
2. Introduce the lesson to the class by explaining that the class will be making slime. Explain the safety procedures for the lesson. Distribute safety goggles to students and make sure that they fit appropriately.
3. Identify materials given to the small groups, as listed in introduction.
4. Distribute one plastic cup and a craft stick to each student.
5. Ask students to put a medium amount of glue into one of the plastic cups. Do not give a specific measurement. Students can use the measuring cups and spoons if they ask but should not be specifically directed to use them. The idea is to let the students experiment with the materials and to arrive at a product without direct instruction. Allow students to make their own determination. This will help to illustrate the point of the activity at its conclusion.
6. Ask students to add about the same amount of water to the cup with the glue.
7. Students should then mix the glue and water together with the craft stick. Do not indicate the speed or duration of the mixing.
8. While the students are mixing, pour some of the borax solution into the second plastic cup and place one on each student's desk.

9. Direct students to add a small amount of the borax solution to the glue and water cup. Students can use the measuring cups and spoons if they ask to but should not be specifically directed to use them.
10. Direct students to use the craft stick to stir the glue, water and borax solution. Do not give directions as to the speed or duration. Do not tell the students when to stop stirring. Allow them to come to this decision on their own. We do not want to determine the outcome of the product. We want to allow students to make different choices so that we will have different forms of slime at the end of this activity to observe and make comparisons of these. During this time, distribute one paper plate and one plastic zip-lock baggie to each student.
11. After most students have stopped stirring on their own, ask the students to take the slime out with their hands and put it on the paper plate. Allow students time to play with the slime.
12. Ask students to describe their slime to the class. Due to the very general directions given to the students, there will be discrepancies in the quality and characteristics of each student's slime. On the board or chart paper, list the characteristics offered by the students. Students should show their slime to the class while describing it. Explain to students that they are gathering data.
13. Review the observations listed with the class. Model asking a question for the class. In this case, "*Why* do people have different looking slime when they used the same ingredients?" or "Why did you get what you got?" Acting as a facilitator, ask the students to analyze what they have seen and heard from the class and to offer suggestions as to why students ended up with such different looking slime. Explain to students that they are developing predictions and explanations.
14. Give students about 5 minutes to discuss in small groups why they think their slime came out differently.
15. Ask each group to share at least one comment with the whole class.
16. List student responses on the board or chart paper. Students may independently arrive at the conclusion that different amounts of glue, water, and/or borax solution were added. They may also conclude that the ingredients were mixed for a longer or shorter period of time or at a faster or slower speed. There may be other suggestions and they should all be listed. If students are struggling, ask strategic questions to guide them. For example:
    - What did you do differently from others in your group?
    - What did you do the same as others in your group?
    - Did you follow the directions exactly?
    - Did you put in the same exact amount of water as you did glue? How do you know it was the same amount?
    - How did you know how much glue/water/borax to put in? Why did you put that amount in?
    - How long did you stir it? Did the slime change if you were stirring longer?
    - How did you measure the amount you put in?

Closure

Have students put the slime in the zip-lock baggie for storage. Have students reflect on their experience and write for 5-10 minutes in their science journals about this activity. The teacher may wish to pose some questions for students to consider.

- What did you make today?

- How did you make it?
- How would you describe your slime?
- How is your slime different than other people's slime?
- Why do you think your slime is different?
- What would you do different the next time you make slime?
- What do you think will happen next time and why?

Assessment

Students will be assessed on their participation in small group and class discussion and the sharing of at least one characteristic of their own slime. We may also assess them on their science journal writing.

Presentation Methodology

Learning is not simply following literal directions to achieve uniform results. It is important that our students develop the ability to analyze and think on their own. We want our students to be able to ask questions, make predictions, gather and analyze data, develop explanations, draw conclusions and effectively communicate ideas. These skills allow students to think creatively, solve problems and invent new solutions. Inquiry-based learning is an effective way to achieve these goals. The goal is to help our students analyze and think about the "why." It is important to encourage students to ask questions. In this lesson, the question is: Why did we get different results? Although this is part of the scientific process, it is not necessarily important whether or not the students have the right answers. In this case, the goal is to stimulate their curiosity and to get them "thinking about thinking." Throughout this lesson it is important that the teacher refrain from giving the students too many specific directions. The idea is to have students create their own measurements and to make mistakes. It is through these mistakes that they can ultimately learn the importance of using science tools and standard measurements so that activities can be replicated. If students become frustrated during this process, give them positive encouragement and let them know that they are doing fine and that they should not worry about it. This should be a fun and creative exploration for the students.

Lesson Two

Lesson Objective

The objective of this lesson is to teach students to use inquiry-based learning to make observations and explore the different properties of a particular kind of slime. The goal for students is to develop their inquiry-based skills by making predictions and observations, gathering information, asking questions and exploring these questions.

Materials

1 pair of goggles per student
2 clear plastic cups for each student
1 craft stick per student
1 bottle of Elmer's® white glue per student or pair of students
1 container of room temperature water per small group of 3 – 4 students
½ cup of 20 Mule Team Borax®
1 liter of hot water
1 2 liter container with lid
1 bottle of liquid food coloring for each small group of 3 – 4 students
1 paper plate per student
1 plastic zip-lock baggie per student

2¼ cup measuring cups per small group (one for glue and one for water)
2 tablespoon measuring spoons for each small group of 3 – 4 students
10 paper towels per small group for clean up
1 sponge for teacher use
Chalk board or chart paper (for teacher)
Chalk or marker (for teacher)

Introduction

In this lesson the students will be given specific directions to follow in creating slime. After creating slime, the students will make detailed observations about the slime and will use these observations to ask questions which will then be explored in a student-directed activity. The teacher's role is to provide the materials, give the specific directions, write down student observations and facilitate the development of ideas. Students should have previous experience measuring both liquid and dry ingredients prior to this lesson. This is necessary to make sure that students are familiar with making level measurements and to avoid unnecessary spills. The teacher should be sure to gather all materials ahead of time. Each small group should have bottles of glue, containers of room temperature water, food coloring, measuring cups and spoons and paper towels. The teacher will also need to get one liter of hot water just prior to the lesson.

Safety

Students should be supervised at all times. The slime can not be eaten. The students and teacher should wear safety goggles when working with these materials. Borax should be kept out of the reach of children. Avoid contact with eyes and do not take internally. Read the caution and directions on the box prior to using.

Procedure

1. Remind the class of the results of the previous lesson when very general directions were given to make slime. Review the safety procedures for the lesson. Distribute safety goggles to students and make sure that they fit appropriately.
2. Identify materials given to the small groups, as listed in introduction. Review classroom rules for sharing materials and working as a group.
3. Distribute one plastic cup and a craft stick to each student.
4. Tell students to measure ¼ cup of white glue and pour it into the plastic cup. Advise students to rest the empty measuring cup on a paper towel and then pass it to a group member to avoid dripping glue on the desk.
5. Tell students to measure ¼ cup of room temperature water from the container on their desk and add it to the glue.
6. Let students know they may add 3-4 drops of food coloring if they want.
7. Direct students to mix the glue and water together with the craft stick. They should mix the ingredients until they have a consistent mixture with an even distribution of glue and water. You may wish to model this for students or draw a parallel with kitchen cooking (for example, making chocolate milk or cake batter).

   As you make the 4% borax solution, explain and show the students what you are doing. Measure ½ cup of 20 Mule Team Borax® and add it to the container of one liter of hot water. Put on the lid and shake vigorously until the borax is in solution. Stop at different points and show students the different amounts of borax that are not yet in solution.

8. Pour small amounts of borax solution into plastic cups and distribute to the students. Give each student slightly more than three tablespoons to account for spillage.
9. Direct students to add three tablespoons of the borax solution to the glue and water cup. Remind students to carefully use the measuring spoons making sure to fill the tablespoon to the top.
10. Tell students to mix the glue, water and borax solution together as soon as they are done adding the borax solution. They will notice right away that something is happening in the cup. The slime will develop around the craft stick. There will be some liquid left over. While the students are stirring, distribute one paper plate and one plastic zip-lock baggie to each student.
11. After the slime has formed, ask the students to take the slime out with their hands and put it on the paper plate. Allow students time to play with the slime. The students should handle the slime with their hands.
12. Ask students to observe the slime using the senses of sight, smell, touch and hearing. **Students should not taste the slime**. After giving the class a few minutes to observe the slime, ask them to share their observations with the class. Write down the students' observations on the board or chart paper. Some examples of observations may include sticky, wet, slimy, gooey, oozing, solid, liquid, color, changes shape or creeping, etc. Remind students that making observations and gathering data are important steps in doing science.
13. This would be a good time to introduce polymer as a vocabulary word. Although it is difficult for young children to conceptualize advanced concepts, it is appropriate to introduce the term to build prior knowledge. It would also be helpful to illustrate the cross-linking nature of the glue polymer, which cross-links when combined with the borax solution. The cross-linking can be felt as the slime forms in the cup due to the production of the higher viscosity slime. Useful illustrations might include paper link or paper clip chains for the polymer and a net for the cross-linked polymer.
14. Review the observations listed with the class. Ask the students to think about questions that could be asked about the slime. Give students 5-7 minutes to discuss this in small groups. You may want to start off the brainstorming session with a question of your own like: Does the color of the slime make it more or less sticky?
15. Each student should come up with one question and share it with the whole class.
16. List student responses on the board or chart paper. Student responses will vary based on student interest, creativity, background knowledge and prior experiences with slime. List all student questions. Here are some possible examples:
    - Are there other kinds of slime?
    - Does the slime bounce?
    - How far does it stretch?
    - Is it a solid? Is it a liquid?
    - Why does it change shape? Why does it go flat? Why does it take the shape of the cup/my hand/the desk?
    - Does it sink or float?
    - What happens when you put it in water?
    - How much does it weigh?
    - How fast does it ooze?

- Why does it feel sticky?

17. Have students store the slime in a zip-lock baggie. The slime can be used again if stored properly.

Closure

Have the class vote on the top three questions that the class would like to investigate. Then have the class vote on those three questions to choose one to investigate. Use the student-directed questions to investigate slime during another lesson. When students are involved in determining what they are studying they are more interested in participating because they are choosing something that is interesting to them. The inquiry method makes learning more meaningful to students because it involves them in decision-making and has high student interest. This method is therefore intrinsically motivating.

Assessment

Students will be assessed on their participation in small groups, in class discussion and on the sharing of at least one inquiry question about the slime they have created.

Presentation Methodology

A large part of inquiry-based learning is utilizing curiosity to ask questions and following that curiosity to investigate the answers to those questions. It is important that our students develop the ability to ask questions about phenomena they come in contact with. It is this skill that helps students to think creatively, solve problems by inventing new solutions. In order to develop these skills, students need to be given opportunities to ask questions and to follow those questions through. In inquiry-based learning, there exists a continuum of teacher and student responsibility or direction. It is advisable to start with modeling questions and guiding students through investigations. Over time, allow students to have more input in the questions that are asked. Perhaps the next step is to have the students vote on a question to explore while the teacher decides how the exploration should be done. As students have more experiences with inquiry-based learning, the responsibility for decision-making can shift between the teacher and students. Ultimately it is desirable to have students creating the questions and deciding how to explore the answer as well. The goal is to stimulate their curiosity about science and to get them thinking as scientists.

Remember that at the beginning of the lesson it is important to remind students of the results of the previous lesson where no directions were given. It is important that our young scientists understand how to use tools, make accurate measurements and understand the value of consistency. After making the slime by following the specific directions given by the teacher, it is beneficial to point out that this was done by replicating the precise instructions and can not be consistently done by guessing. Another important component of this lesson is generating student observations of the slime. Making observations is an important part of inquiry-based learning and the scientific method as observations help us to make predictions and hypotheses and to draw conclusions. Students need multiple learning opportunities to make observations so that they can practice and develop their science skills.

Lesson Three

Lesson Objective

The objective of this lesson is to teach students to use inquiry-based learning to ask questions and find ways to explore answers to those questions. The goal for students is to develop their inquiry-based skills by asking questions, designing and conducting experiments, gathering and analyzing data, drawing conclusions and effectively communicating.

Materials

1 pair of goggles per student
Glue slime, as made in previous lesson
Bubbles
1 plastic cup per student
1 craft stick per student
1 container of room temperature water with easy pour spout
½ teaspoon of sodium polyacrylate per student
½ teaspoon measuring spoon for each small group of 3-4 students
Black permanent marker for each small group of 3-4 students
1 6-inch piece of wax paper per student
20 paper towels per small group for clean up
1 sponge for teacher use, if needed
1 stopwatch
Chalk board or chart paper, for teacher
Chalk or marker, for teacher
1 science journal and pencil for each student

Introduction:

In this lesson, the students will be given the opportunity to not only generate questions of personal interest, but will also be given the opportunity to choose a question to investigate. The students will use inquiry-based learning and hands-on investigation to attempt answering the question. To do this, the students will need to ask questions, construct an experiment, make predictions, run fair tests, take measurements and observations, gather data, draw conclusions and communicate what they have learned. This lesson builds on the previous two lessons and provides a host of questions from which the students can draw. The content of this lesson will depend on the question the students choose to investigate. This is a valuable opportunity for the students to design a test on their own. The teacher's role in this lesson is to model good scientific thinking, to guide students in their thinking and planning, to ensure safety in the classroom and to pose questions as appropriate to guide students as they learn how to do inquiry. The details of the lesson can be modified based on student interest and direction.

Safety:

Students should be supervised at all times. None of the slimes in this lesson can be eaten. The students and teacher should wear safety goggles when working with these materials. As noted before, borax should be kept out of the reach of children. Avoid contact with eyes and do not take internally. Read the caution and directions on the box prior to using. Sodium polyacrylate is non-toxic and non-hazardous but should be handled carefully and never put near the nose, mouth, eyes or ears.

Procedure:

1. Review the list of *student-generated questions* that the class came up with during the previous lesson. Although it is not necessary to use these questions it will allow the class to utilize their prior knowledge. Have students vote on the question they want to explore. We will use the question "Which slime oozes the fastest?" as an example but any student-generated question could be used here.

2. Have students work in small groups of 3 – 4 students to *brainstorm* ways to investigate the answer to the chosen question. Give students 10 minutes to come up with ideas. If they are struggling, stop early and ask for the groups to share the ideas they have come up with.

3. Make a list of all the ideas given on the board or chart paper.
4. Have the class discuss the ideas and ask them to determine which idea will work the best. As a facilitator, ask probing questions that guide them towards a reachable goal.
5. Remind students that they need to use materials available to them and that they need to be able to *perform the test on their own*. The students should be instrumental in *designing the experiment*. For example, a group of students who have decided to investigate how fast different slimes ooze will need to choose slimes to test. The teacher may guide them to choose a reasonable number of slimes and may offer suggestions of safe ways to use slimes. In addition, from their hands-on experiences with slime, the students may recognize that some slime stops oozing when it has "flattened out" and may suggest that it would be better to try to get it to roll down a surface.
6. The students need to determine what surface the slimes will be "rolled" down. In this example, students look around the classroom and decide that the big book holder will work well. The teacher introduces the vocabulary word slope and it is compared to the concepts of hill, mountain and angle.
7. The students decide to drop three kinds of slime down the "slope" and decide that one student will watch to see which slime gets to the bottom first. The teacher introduces a new tool, a stopwatch, to help facilitate the accurate assessment of the "winner." The idea of accuracy is emphasized.
8. The students *gather the necessary materials* to perform the experiment. In this example, bubbles, glue slime and water slime are used. The glue slime is used from the previous lesson and commercial bubbles are found in the classroom.
9. Water slime is prepared as follows. Review the *safety procedures* for the lesson. Distribute safety goggles to students and make sure that they fit appropriately.
10. Distribute a plastic cup to each student along with a craft stick.
11. Give a ½ teaspoon measuring spoon, a black permanent marker, and a small bowl of sodium polyacrylate to each small group.
12. Have each student use the black marker to make a horizontal line on his or her plastic cup marking a little less than halfway up the cup.
13. Have each student measure ½ teaspoon of sodium polyacrylate into his or her plastic cup and then collect the remaining sodium polyacrylate.
14. Have each student use the container of room temperature water to fill his or her plastic cup up to the black line.
15. The sodium polyacrylate is a hydrophilic polymer and will absorb the water quickly making slime in the cup. If a more liquid slime is desired, add water. If a more solid slime is desired, add more sodium polyacrylate.
16. After the slime has formed, ask the students to take the slime out with their hands, using the craft stick if needed, and put it on the paper plate. Allow students time to play with the slime. The students should handle the slime with their hands.
17. Give students the opportunity to touch the three kinds of slime and ask them to *make a prediction* about which slime will be the fastest. They should also try to explain why they have made this prediction.
18. The students then begin *running the tests* by dropping one slime at a time down the slope with one student dropping the slime at the top. The other student is holding the stopwatch and

is watching the bottom of the big book stand. The other *students gather and record the data* in their science journals.

19. After the three slimes have been tested it may be useful to *rerun the tests* to make sure that the results can be duplicated.
20. Students should *analyze the data* that have been gathered to draw conclusions about which slime oozes the fastest.
21. Students should attempt t*o communicate their results* through writing, graphs and/or illustrations.

Closure

The students should reflect on the inquiry experience. This is beneficial as it helps students to see what they have learned and how they have contributed to their own learning. The students should write about their investigation and experiences in their science journals.

Assessment

Students will be assessed on their participation in small groups and in class discussion, the creation of water slime and their communication of test results in their science journal.

Presentation Methodology

Inquiry-based learning is an effective way for students to learn about science content because it involves students in their learning. When students are able to make decisions about what they are learning and how they go about learning, they are invested in the learning process and it becomes more meaningful to them. It is a very interesting and exciting learning process. The goal is to stimulate student curiosity about science and to get them thinking. Although a particular student-generated inquiry activity has been presented here, it is important to understand that any student-generated question can be used. The inquiry method is the most useful component to this lesson. This is the idea that students can take ownership of their learning while developing science process skills. There are a number of other questions about slime, and other natural phenomena that can be used instead. The list of questions is limited only by the imagination and creativity of the students and the teacher.

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