Part Ia: Explanation of Topic Chosen: Matter

Imagine a world without matter. Impossible to do, right? Everything that exists within the universe is made up of matter. From an intimidating skyscraper to a microbial virus, all things consist of this scientific material called matter. Matter can be defined as “anything that has mass and takes up space” (Cuevas, et al. 2005). All things possess unique physical and chemical properties of matter. The variety of things in our world can also be contributed to the different states of matter, each having their own characteristics and properties. As put forth in part Ia of this assignment, the following paragraphs will outline the above-mentioned states, characteristics, and properties of matter.

On earth, there are three main states that matter exists in: solid, liquid, and gas. A solid object has a definite shape and a definite volume. Solids can keep shape on their own unless an outside force is exerted on them (Matter 2005). If a solid object were to be moved from one place to another, its shape and volume would not change. Yet, a solid’s volume can be affected only by temperature. Temperature can be defined as the measurement of the average motion of the molecules in an object (Cooney, et al. 2000). An increase in temperature of a solid object may cause the molecules to expand, making them move faster and farther apart. Whereas, a decrease in the temperature of a solid may cause the solid particles to contract; therefore, the molecules would move slower and closer together. This movement of molecules is most times unobservable to the naked eye; however, during expansion and contraction, one may hear creaks of floorboards or clanks of metal when the heating furnace turns on in the home (Matter 2005). This indicates that the solid object’s volume has been affected by temperature.

The second state that matter exists in is liquid. Liquids are known to have a definite volume but no definite shape. Liquid particles take the shape of the container they are in. For instance, water in a glass will take the shape of the solid object. If one moves a liquid, it will take the shape of the container but it will not lose its volume. Like solids, liquids, too, are affected by an increase or a decrease in heat energy. Liquids will expand when heated and contract when cooled. This is an observable characteristic when looking at a thermometer. When the liquid mercury inside a thermometer is heated, the mercury begins to expand and rises in the tube. When the mercury is cooled, it contracts or lowers in the tube. The measurement of temperature of an object is an example of how a liquid’s volume can be affected.

Gases are the third main state of matter. Gas molecules do not have a definite volume or shape; rather, they occupy the volume and assume the shape of the container they are in (Cooney, et al. 2000). Gas molecules lack “intmolecular force.” That is, gas particles are not held together tightly and move independently of one another (Matter 2005). Like solids and liquids, a gas’ volume can be greatly affected by temperature. However, unlike other states of matter, gases can be compressed greatly by exerting pressure, which can drastically reduce the volume of the gas. This property is evident in aerosol spray cans.

Molecules that make up matter have an attraction among them and are constantly in motion. In a solid, a strong attraction holds the particles close together. Instead of moving, each particle vibrates. In a liquid, the particles are not held together as tightly; therefore, the particles are able to move past one another so the liquid can flow into different shapes. In a gas, there is a very weak attraction among particles. The particles move quickly and freely in all directions leaving a lot of empty space between them. The
movement and closeness of molecules determines the density of that type of matter. In other words, density is “the amount of matter in a given space, or volume” (Cuevas, et al. 2005). Therefore, if there is more matter (closer molecules) than it is said to be denser, while if there is less matter (farther apart molecules) than the object is less dense.

To determine the density of an object, one must first identify the mass and volume of that item. Mass can be defined as the “measurement of the amount of matter in an object” (Cuevas, et al. 2005). Mass remains constant from one location to another. In fact, the mass of an object is the same no matter where it is located within the entire universe. Altering the amount of matter, or the number of molecules, that make up the object is the only way to change the mass of the object.

As mentioned in above paragraphs, molecules are attracted to one another. Depending upon the mass of the object, the force of the attraction may be tiny for normal matter, such as a paper clip, or stronger for larger matter, such as a truck. This strong attraction is known as the force of gravity (Matter 2005). This attraction of gravity is felt as “weight” on earth. Weight is not the same as mass; rather, it is the measurement of the gravitational force exerted on an object (Cuevas, et al. 2005). The value of weight is dependent upon the location of the object and it’s relation to the center of the earth’s gravitational force. Therefore, a person would weigh less on the moon because the moon is farther away from the center of the earth’s gravitational force; yet, the same person would still have the same mass on the moon as they would have on the earth (the number of molecules would not change).

In correlation to mass and density, all matter takes up space. The space that a certain amount of matter takes up is known as the object’s volume. Typically, volume is the measurement of an object in a three dimensional space and is usually measured in cubic centimeters or cubic inches (Cuevas, et al. 2005). Characteristically, volume is not altered in a specific type of matter. For instance, if one were to take a ball of clay, at a certain volume, and change it into a flat object or a cube it would not lose its volume. In other words, it is still taking up the same amount of space. This is because no two types of matter can be in the same place at the same time. An observable example of this is when an empty glass is filled with water. One would notice that bubbles are created when the water is forced into the solid object, the glass. Scientifically, the water molecules have now filled in the space where air molecules once were; hence, the air molecules were pushed out of the glass creating the bubbles escaping at the top.

In conclusion, matter can be found everywhere in the universe. Any object, whether it is a solid, liquid, or gas, can be identified having properties such as mass, weight, density, and volume. The molecules that make up matter are held together by an attraction and are constantly in motion. This report has outlined some of the types, characteristics, and properties of matter.

Part I b: National Science Education Standards

The chosen topic for the pre-assessment report incorporates identifiable National Science Education Standards. These specific standards provide approaches for teachers to utilize, so that they may encourage and guide students to develop certain scientific skills. Some of the relevant standards under the concept of the introduction to matter directly correlate to the Physical Science Content Standards. More specifically, some standards are listed under the “Properties and Changes of Properties in Matter.”
National Science Education Standard code PS 1a addresses the scientific fact that substances have characteristic properties, such as density, and that a mixture of substances can be broken down into its original parts through one or all of a substance’s characteristic properties. NSES code PS 1b summarizes how substances react with one another to form new substances by chemical means. It also encapsulates the law of conservation of mass and that substances can be categorized into groups. NSES code 1c concentrates on the breaking down of chemical elements as well as the combination of the 100 elements that make up living and non-living matter in the universe. In addition to these standards, this topic of matter incorporates Science and Technology standard code ST 1: the abilities of technological design and code ST 2: understandings about science and technology (Holt, Rinehart, and Winston 2005).

Part I.c: Children’s Misconceptions about Matter

Much research has been conducted to determine how children understand, classify, and interpret scientific information related to matter. To gain the most accurate data about how children develop scientifically, researchers first examined the theories of Piaget. Throughout much of the 20th century, the education of science was based primarily on cognitive development of a child’s logical capabilities, which is also known as “global restructuring” (Nakleh, Samarapungavan, and Saglam 2005). However, in the 1980s, researchers developed another theory known as the “Novice-as-Theorist.” Researchers believe that this explains how people suddenly produce ideas about scientific phenomena. They hypothesized that it was a way for children to explain and organize events and materials in nature. Most recently, researchers speculate that children’s knowledge about science can be organized into three categories: matter, processes, and mental states (Nakleh, Samarapungavan, and Saglam 2005). For the purpose of this report, the information that follows will entail a detailed explanation of children’s thinking about matter.

There is a notion that children develop ideas about science from their everyday experiences and those ideas are adapted and expanded upon throughout formal science education. When asked about the particulate nature of matter, elementary level children responded more descriptively rather than explanatory. In other words, students described states of matter and phase changes using descriptive words by means of the senses. They did not, however, explain the states and changes with a deep understanding of how matter interacts in the natural world. According to a research study done by Nakleh at al (2005), these students operate through “macroparticulate frameworks,” which is that they believe that matter can be broken down into tiny pieces by physical means. This study was also conducted with secondary students who additionally conveyed their knowledge through the macroparticulate frameworks. They described observable properties of matter and the behavior of various substances. It is noted, though, that children of all levels have difficulty restructuring their preconceived notions about matter in nature from macroscopic to microscopic, also known as the atomic and molecular basis of matter (Nakleh, Samarapungavan, and Saglam 2005).

To gain further insight into how students perceive scientific phenomena, such as matter, Nakleh et al (2005) conducted interviews with children from the middle level. The interviews consisted of open ended questions related to properties of matter. Some examples of the questions were: “Can you describe the qualities of water?” and “This is a
sugar cube. Can you describe the qualities of this sugar cube? The follow-up questions were based on student responses to the initial cue. For instance, if a student responded to the water quality question using the word “molecules or particles”, then the next question by the researcher prompted the student to explain the term in more depth. This pattern continued until the student explained as much as he/she could about the topic.

The data collected from this study of middle level children was compared to previous studies with elementary level children. The results of this particular study indicated that middle level students are preliminarily advancing towards a more scientifically precise understanding of matter. However, about one-third of the students still had misconceptions about matter in the natural world (p.607).

Additionally, misconceptions arose about the size of molecules and atoms; hence, this type of fallible information leads to misunderstandings about density, mass, and weight since each of these characteristic properties is related to the size of particles and how they make up matter. The research indicates that some students thought they could see molecules and atoms in their simplest form through a regular compound microscope. Further difficulty that the students had was an understanding that larger, solid objects were made up of molecules and atoms (particulate matter); yet, as mentioned previously, children knew that solids could be broken down into smaller pieces. Moreover, Nakleh et al (2005) concludes, from the data, that middle level students are in a “transitional phase,” which is when earlier conceptions of scientific phenomena are becoming disjointed or fragmented (p. 608).

In conclusion, children’s development of their own ideas and beliefs about natural phenomena stems from daily experiences in the natural world. As children age, their beliefs and ideas become increasingly fragmented due to modifications and revisions throughout formal science education. The research data above indicates that there is a need to collect more information about how children learn scientifically and designates the need to develop instructional strategies that support students preconceived notions about matter.

**Part II a: Demographics of Class**

MaST Community Charter School is located in the Northeast region of Philadelphia. This class is composed of 27 students between the ages of eleven and twelve years old. 82% of the students in this class are white, 4% are African American, 7% are Middle Eastern, and 7% are bi-racial. The gender ratio of these students is sixteen girls to 11 boys. In this class, there are three students with individualized education plans and two other students receive instructional support. In addition, two students are mentally gifted and receive enrichment on a weekly basis. All of the students in this class reside in the northeast region of Philadelphia and its surrounding suburban counties.

The pre-assessment questions were distributed at the beginning of the 65 minute class period as part of their “Daily Science Workout,” which is a ten minute daily warm-up exercise at the beginning of each lesson. I explained to the students that they were answering questions about a topic that they would be learning later in the school year. I articulated that their responses needed to be to the best of their ability; however, it was expressed that it would not count against them for a wrong answer. Some students were still confused as to why they were doing this now in the school year and I explained that I
wanted to know their thoughts about this topic and that I would be using their responses in a graduate level class that I was taking. They seemed satisfied with that explanation and answered the questions accordingly.

The overall time for the class was about 20 minutes. Some students were slow to start, while some students plowed right through. As I monitored, I helped only the students who had difficulty reading and understanding the questions. All student responses are based on their own understandings and interpretations.

Part II b: Rationale for the Questions Used

According to the National Research Council, educators need data taken from research studies to assist them in implementing project-based or inquiry-based tactics to the teaching and learning of scientific concepts (2000). Without preliminary knowledge of student understanding, teachers cannot effectively develop, plan, and implement experiences that help students acquire skills and abilities related to scientific concepts. Therefore, in order for me to successfully educate my students about a specific topic, I needed to have a baseline assessment of my current students’ understanding of matter.

The decision to ask the questions for this pre-assessment report was based on several factors. I devised a plan of when and what was I going to be teaching in the early spring and decided on my third unit: The Introduction to Matter. Next, I read through the book and noticed that mass, weight, density, and volume were all mentioned in the first chapter. These are important scientific concepts to learn because they are relevant in everyday life, which would make teaching and learning of this concept authentic to my students.

While reading through that first chapter, I noticed that the teacher’s guide listed student misconceptions about particular concepts of matter. After reading though those “misconception alerts,” I realized that I had my own difficulties deciphering through that information at the same age. Furthermore, I inferred that my students would have the same misconceptions that I had. So, I made my decision to develop questions to pre-assess my students’ knowledge of density, mass, and volume.

Part II c: Student Responses

Analyzing data is a key component when researching how children think about a specified topic. The data I gathered was based on student responses to two questions pertaining to the characteristic properties of matter, specifically density, mass, and volume. I coded the student answers according to the vocabulary set forth in their explanations. For example, I noted cue words, such as “heavier, bigger, thicker, etc.” to devise a category based on the observable characteristic of size. Some students used more explanatory terms, while others answered in complete sentences without supporting the reasoning behind their thoughts.

Student responses were coded as follows for question one:

<table>
<thead>
<tr>
<th>Categories</th>
<th>Description</th>
<th>Number of student responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>larger, smaller, bigger, thicker</td>
<td>2</td>
</tr>
<tr>
<td>Weight</td>
<td>heavier, lighter,</td>
<td>7</td>
</tr>
<tr>
<td>Texture</td>
<td>wet/dry</td>
<td>3</td>
</tr>
</tbody>
</table>
composition | more/ less/ same matter, mass | 4
material | brick had most matter and mass | 21
no explanation | answered correctly without detailed analysis | 4
Volume | amount of space something takes up | 7
miscellaneous | responses that did not fit into other schemes | 3

After examining this information, it is evident that 78% of the students predicted that the brick had the most matter and the greatest mass. Yet, their reasoning for this assumption varied. For instance, 26% of the students associated the brick’s weight or heaviness with having more matter and mass than a dry sponge. Those who responded in this manner did not, however, make mention of the term “molecules” or “particles” that make up the brick and the sponge. Rather, one student responded that “the brick was made up of more things,” insinuating that he was aware of the fact that the brick can be broken down into smaller substances. This particular example can be referred to as the previously mentioned “macroparticulate frameworks.”

Interestingly, all of the seven students that made reference to volume were correct thinking that volume was the amount of space that a certain amount of matter takes up. Yet, only some of them were able to make the connection to the statement listed in the problem set that the brick and the sponge took up the same amount of space. Some students were confused and responded with “matter is what space it takes up” and “volume and mass are almost the same thing.”

Student responses for question two are as follows:

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<thead>
<tr>
<th>Categories</th>
<th>Description</th>
<th>Number of student responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>larger, smaller, bigger, thicker</td>
<td>2</td>
</tr>
<tr>
<td>Weight</td>
<td>heavier, lighter</td>
<td>1</td>
</tr>
<tr>
<td>Composition</td>
<td>more/ less/ same matter (&quot;items, things&quot;)</td>
<td>6</td>
</tr>
<tr>
<td>composition of bag</td>
<td>material, size</td>
<td>5</td>
</tr>
<tr>
<td>Material</td>
<td>cotton was least dense bag</td>
<td>3</td>
</tr>
</tbody>
</table>
Student responses for question two varied a bit more than in the previous question. Question two was designed as open-ended so that data could be recorded on middle school student interpretations about mass and density. Students were asked to decipher whether a bag of tomatoes and a bag of cotton balls, each having the same mass, was denser than the other. Based on that question alone, 26% of the students wrote that they thought the tomatoes were denser because they had more mass. This clearly is a misconception based on the fact that it states that both bags have an equal mass. Furthermore, some students stated that density of the bags was based on the number of “things” or items in the bag. Some students even thought that the material the bag was made up of determined the denseness of the substance. In addition, it is evident in the data that students associated density and mass with the size of either the objects or the bags. For example, one student wrote: “mass means weight.”

Overall, student responses were coded according to how the students conveyed their thoughts about the topic. Results were tallied and scored accordingly.

Part II d: Analysis of student responses

The concept of matter, in particular mass, density, and volume, is a difficult one to grasp. Middle school aged children have many misconceptions about this subject as evidenced in the above data tables. As mentioned in the research, students base their knowledge on observable characteristics. This concept holds true to this particular group of students. They explained density and mass based on the visible, tactile objects mentioned in the pre-assessment question. In other words, some of the students envisioned an actual brick and a dry sponge sitting on their desk. This theory is supported by a statement made by a student who claimed, “I think the brick and the sponge have the same mass because they look to be about the same size.” Based on
observation skills, the first sensory motor that they use to process information is their sight. Next, students might have imaginarily utilized the sense of touch. They might have imagined themselves lifting both objects. This type of thought process may lead students to make inferences about mass and associate it with weight. An example of this response was “I think the brick would be heavier than the dry sponge.”

As mentioned previously, children develop ideas about science from their everyday experiences and those ideas are adapted and expanded upon throughout formal science education. Using their senses, these children adapted their knowledge of matter, mass, density, and volume and applied it to what they previously knew from either their own experiences or what they had learned in past years through science education. This theory is evident with a response such as, “the brick was made up of more things.” This retort implies that this particular student knew that the objects are made of smaller substances (molecules); hence, this makes reference once again to the macroparticulate frameworks reported by Nakleh, Samarapungavan, and Saglam (2005).

Pre-assessing my students about this particular topic has given me insight about what they know about matter. Interestingly, it has now shaped a framework for how this concept needs to be taught and how to teach students to alter their previous conceptions.

Part II c: Implications in the Classroom

As indicated earlier in the report, there is still a need to collect more information about how children learn scientifically. This is evident in the sample of responses gathered for this report. However, based on these findings I am able to develop various instructional strategies needed for formal science education.

The class with which this study was conducted informs teaching in the general sense. It implicates that students have misconceptions about the natural world. This affects education greatly in the sense that it reiterates that reform is needed to successfully educate students to become scientifically literate citizens. A scientifically literate citizen possesses a vast understanding of scientific principles and theories/ideas. They are able to make real-life connections to scientific phenomena.

In general, research is being conducted on a consistent basis in order to inform teachers and students about scientific occurrences. According to Krajcik, Czerniak, and Berger (2003), students should have a meaningful understanding of science. That is, learners should scaffold and make connections among scientific ideas and personal experiences or viewpoints. Moreover, students should be able to apply knowledge gained in a classroom setting to real-life.

These findings enable me to enhance the development of my formal educational strategies. The results of this study allow me the opportunity to gain insight into my students’ background knowledge about matter, in particular mass, density, and volume. Although students have difficulty restructuring their preconceived notions about matter in nature from macroscopic to microscopic, I now have a better understanding of how to designate and expand instructional strategies that support students’ preconceived notions about matter. For instance, I will focus on the concept that all matter on earth is made up of molecules. I will allow students to investigate and make connections to real-life applications through the development of a driving question. A driving question is a project-based question that enhances students’ abilities to utilize prior knowledge to link previously learned material to new and cross-curricular information (Krajcik, Czerniak,
and Berger 2003). The driving question focuses students’ learning on discovering new information through inquiry and hands-on activities. This style of teaching science does not isolate one particular aspect or concept. In fact, it allows students to make connections using an overall project.

Furthermore, using the pre-assessment information outlined in this report will assist in the teaching and learning process. This will allow me the opportunity to meet and attain goals laid forth in the National Science Education Standards. As an educator, I will benefit by having a baseline assessment of student knowledge so as to effectively and formally teach scientific concepts to encourage my students to become scientifically literate in the area of matter, specifically mass, density, and volume.
References


