.

Applied Origami in Physical Science, Biology and Chemistry

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Abstract:

This curriculum unit is designed to integrate origami with physical science, biology, and chemistry concepts. Students will learn origami and use this learning to make scientific and mathematical models. Students will begin by making classic origami models, such as the crane and the frog. As we progress in our learning of origami students will make models of atoms, molecules, compounds, and DNA and eventually make more complex structures such as the buckyball. Students will also make 3 dimensional geometric shapes and explore the uniqueness of the cube. A step-by-step instructional strategy making use of videos is used throughout to accommodate the all-inclusive heterogeneous classroom.

Overview:

Origami is an ancient art that has been taught and practiced for hundreds of years. It is the art of folding paper. Recently these principles of origami have evolved into origami engineering. Scientific applications of origami techniques are being utilized in various engineering projects particularly in designing telescopes that deploy in deep space as well as in medicine, and manufacturing. As more and more individuals have become interested in origami as a process, the need for a standardized nomenclature has been satisfied, along with a set of rules for folding and creasing. An offshoot of origami is modular origami, which is made by taking multiple pieces of paper, folding them into similar units and connecting them to together. It is my desire to share with my science students the fundamentals of origami, and modular origami to develop models related to physical science, biology, and chemistry concepts in an attempt to improve student performance on the Pennsylvania Keystone Examinations in both math and science.

Rationale:

A.P. Randolph is a career and technical high school with a strong academic program as well. Students that attend our school have the opportunity to prepare themselves for an entry-level position in their chosen technical field of study. These fields of study include, welding, vending machine repair, construction, auto collision repair, automotive technology, health related technology and dental assistance. Additionally students may decide to pursue post secondary education at an academic college or university or a trade school. Sadly enough, many of our students do not avail themselves to the vast opportunities that may lie ahead of them. This may be a result of a lack of preparation or a lack of desire or a combination of the two. I say this because only 8.3% of our students scored advanced or proficient on the Algebra Keystone exam and no students scored advanced or proficient on the Biology Keystone exam (*Pennsylvania Department of Education*, 2012). Attendance is also an issue for a significant number of students, 15% of our students are chronically truant and 69% percent of our students are chronically tardy daily.

Prior to becoming a teacher 32 years ago, I was a Chemical Engineer and worked in that capacity for a number of years before becoming a building maintenance engineer for the city of Philadelphia. In both of those career situations, reading schematics, blueprints diagrams, and directions were essential. I began teaching on the college level shortly after I received my MBA. It was during my stint teaching undergraduate courses at a community college that I discovered that I had a passion for teaching. This passion led me to obtain my master's degree in secondary science education. It is this passion that drives me to undertake this challenge to incorporate the fundamentals of origami engineering in the teaching of general science.

I currently teach chemistry and 9th grade physical science. Many of my classes are double periods (block) and meet for 2 marking periods daily. All classes are heterogeneous and have mixed ability levels, including about 17.4% special needs students. It is my intention to create some excitement in the classroom by engaging my students in a hands on, minds on, interactive learning activity in which they will be able to see the results of their learning. Being exposed to origami engineering as a process has the potential to enhance their skill levels in geometry, algebra, reading and following directions. It is also my hope that general comprehension and critical and creative thinking skills will rise. I will approach my instruction using traditional as well as nontraditional methods. Introducing vocabulary first, followed by modeling and then providing stand up instruction followed by an activity. This approach is called, "I do, we do, you do" by many teachers and works well regardless of grade group including university level learners. In this curriculum unit students will be exposed in a non-intimidating way, to sophisticated mathematic applications, vocabulary, and modeling activities, which will lead them to create 3D structures relevant to physical science, biology, and chemistry. Traditional instructional methodology incorporating the use of technology will be utilized as often as possible. Computer aided instruction will be used to provide students will repetitive instruction on creasing and folding and to facilitate extended learning activities.

In all of their CTE classes, students learn skills that enable them to do “something”. This “something” that they learn to do often has immediate applications. Such as in auto mechanics class students might learn how to repair a flat tire or in construction technology students might learn how to frame a building. In content specific courses like physical science, chemistry, and biology many of the key concepts are abstract. Students will learn about covalent and ionic bonds but will never see them. This unit of study will attempt in a novel way to provide students with a “do something” activity that may enhance their understanding of some key concepts in science and mathematics. Students will build models representing abstract scientific concepts as well as concrete scientific models using the processes of Origami, Modular Origami and Kirigami.

To do well on these Keystone exams students must be able to do more than just recall facts and equations. These exams actually assess a student’s depth of knowledge (DOK), at various levels. These levels range from simple recall (at the lowest level) to what is called extended thinking (at the highest level). Currently students are evaluated in three identified areas, Algebra 1, Biology and literature. These exams incorporate a combined application of Blooms Taxonomy of Educational Objectives and Webb’s Depth of Knowledge. It is my desire through this series of lessons and activities to increase student’s knowledge base and increase their cognitive ability as it directly relates to their performance on these standard assessments. There are several offshoots of origami that offer the potential to induce higher order thinking. One such subset of origami modular origami. We will be making use of that process to make some of our models.

Origami used in the Teaching of Science and Mathematics:

A study was conducted by James Davis, Ray Leslie, Susan Belington, and Peter R. Slater, which sought to investigate the development of new science modeling concepts based around the art of origami. It was thought that a hands on approach to building models would help students rationalize why molecules posses a given structure. Origami as a modeling system has been used as a teaching aid in mathematics (Mitchell, 2005) but can easily be transformed into a versatile vehicle for explaining concepts central to many biological and chemical systems. The methodology of their project centered on using origami as a hook for capturing the interest of the pupils. To engage students it was clear that activities needed to be highly engaging, somewhat challenging but also differentiated for various ability levels. It was shown that origami provided a multitude of possible models and their relevance to molecular architecture can be tailored to specific examples. On a separate and much broader level it was proven that origami could be used to show how a precise sequence of folds can produce a desired scientific model. As a part of this study a website was constructed and the basic, step-by-step instructions for a range of models were made available for screen, print or download. Teachers and students accessed the site and it was found sufficient for simple models. It was concluded that origami activities proved to engage students and this type of modeling system was worth considering as a viable teaching platform. (Chemistry Education Research and Practice, 2010, 11, 43-47)

Origami and Cognitive Development:

In a study to explore if origami could be used to train spatial thinking in elementary-age children, conducted by Holy A. Taylor and Thors Tenbrink it was determined that cognitive ability was improved. The authors contend that visuospatial thinking underlies reasoning in (STEM) domains (Uttal et al. 2012). The authors further suggest that embedded in origami are many opportunities for visuospatial thinking. While a student is folding a model, they may be able to visualize the completed model throughout the folding process and possibly see the connection between the folds and the completed model. The authors of this study further contend that origami imbeds visuospatial thinking in its instructions, both verbal and graphic, including reversing, rotating, and inverting a model, or translating steps to the mirror side (Taylor & Tenbrink, 2013). The study sought to capture evidence of visuospatial thinking while pupils were engaged in the origami process. Students were asked to think aloud while making their model. To quantify the cognitive process evident, cognitive discourse analysis (CODA; Tenbrink 2008) was used. In conclusion it was determined that origami instructions, which provided verbal as well as visual directions has the potential for improved cognitive development as well as spatial thinking. It was shown that students who completed a program of origami and paper engineering showed significant gains in their spatial thinking (Taylor and Huntton).

Background

A brief history of origami:

“Origami is a form of visual or sculptural representation that is defined primarily by the folding of paper” (Wu, J. 1999).

The exact origin of the art of origami is unknown. Origami was initially known as orikata (folded shapes). In 1880, however, the craft became known as origami (Wu, J 1999). The term origami comes from the Japanese words oru (to fold) and kami (paper). It is speculated the term was chosen because the characters used to write this term were easy for schoolchildren to learn to write. When origami was first practiced, it was a craft for only the elite. Japanese monks folded origami figures for religious purposes. It was also used in various formal ceremonies, such as folding paper butterflies to adorn sake bottles at a Japanese couple’s wedding reception (Relente & Steinert, 2018). Tsutsumi, folded paper gift wrappers, were used in some ceremonies to symbolize sincerity and purity.

Tsuki, folded pieces of paper accompanying a valuable gift, are another example of ceremonial paper folding since these models would act as a certificate of authenticity.

As paper became more affordable, common people began making origami figures as gifts or creating folded cards and envelopes for their correspondence.

Origami also started to be used as an educational tool, since the folding process involves many concepts that are relevant to the study of mathematics. The kindergarten movement in Germany, which was introduced around 1835 by Friedrich Frobel included paper folding. The master Yoshizawa Akira presented the first works of original modern origami in the 1950's (Hinders D., 2018).

Incorporating origami into science instruction:

Through the use of origami model making students will gather a better understanding of what constitutes a physical or chemical change as well as how qualitative and quantitative observations differ. We will also reinforce the concepts of density and naturally occurring shapes in nature. As we progress with the origami process we will build models of an atom and eventually build a molecule.

How we teach must reflect how our students learn, it must also reflect the world they will emerge into. This is a world that is rapidly changing, connected, adapting and evolving. Our style and approach to teaching must emphasize the learning in the 21-st century (Chruches A. 2008).

We will be using traditional origami as well as variations thereof. Let's first discuss using traditional origami. To do such we must become familiar with the nomenclature, symbols, and techniques. The folds are described using the Yoshizawa-Randlett diagramming system. There are two main types of origami symbols, lines, and arrows (Engle, P.1989). The arrows show how the paper should be creased or folded. The lines show various edges:

- A thick line for the edge of the paper
- A dashed line for a valley fold
- A dashed and dotted line for mountain folds (there may be one or two dots per dash depending on the author)
- A thin line for a previous fold
- A dotted line for a previous fold that's hidden or sometimes a fold not made yet

For a detailed and comprehensive review of the symbols and operations that we will be using please log on https://en.wikibooks.org/wiki/Origami/Techniques/Yoshizawa-Randlett_system#Operations

According to Robert Lang in a series of articles entitled Origami Diagraming Conventions (1989-91), drawings should indicate all relevant information and verbal instructions should not be necessary. Because many people work better from verbal descriptions than from diagrams, sufficient verbal instructions should be included. Dr. Lang offers an origami vocabulary for verbal directions:

- in, inner, central: toward the center line (lateral motion)
- out, outer, out to the sides: toward the edges
- up, upper, toward the top of the page
- down, lower: toward the bottom
- near, toward you: toward the reader
- far, away from you, behind: away from the reader
- raw edge: the original of the paper (not a folded edge)
- folded edge: obvious. Edge may indicate a folded edge; raw edges should always be qualified
- ply: an individual thickness of paper (Waterbomb base has 4 piles on each side)
- layer: a separate thickness (a Waterbomb Base has two layers on each side but for piles)
- Into the interior: hiding a flap

Science and math concepts to be covered incorporating origami model making:

- Mass, weight, size, density, and volume: Density is a major concept in physical science and chemistry. Students often struggle with the arithmetic involved, mass divided by unit volume (D=m/V). They also often have trouble distinguishing between a physical change and a chemical change. Lesson# 3, is an example of classical origami. Making an origami cube is intended to help students realize the density of a substance is constant. Students will also gain practice measuring, weighing and performing calculations.
- The relationship between atoms and molecules: In both chemistry and physical science students are taught about elements of the periodic table. We emphasize that an element is made up of only one kind of atom, and a molecule is made up of two or more atoms bonded together. Lessons #5 and #6 are examples of modular origami. You will guide students to make models of diatomic molecules as well as compounds, using modular origami.
- Distinguishing between physical and chemical changes: Lesson #3 is also intended to help students to understand that even though we have changed a two dimensional

piece of paper to a 3 dimensional piece of paper by folding and creasing it, we have not altered the chemical composition of the paper.

- Performing calculations involving density: Lesson #3, will also give students practicing calculating density.
- The role of models in mathematics and science: Lessons #3,4,5,6, and 7 all intend to have students create scientific models using origami to enhance their understanding of specific science concepts.
- The structure of DNA: Lesson #4, is intended to give students an opportunity to make an origami model of DNA. As students complete the model, they fold and twist the template to form double helix structure.
- Newton's Third Law of motion: Lesson #2, is intended to give students additional practice reading classic origami diagrams, as well as practice folding and creasing paper. After making the origami-jumping frog, students will be challenged to discover ways to make the frog jump further.
- Area, volume, surface area: Lesson #3, making the origami cube in the extended reading and writing ask students to compare the area, volume, and surface area of the flat sheet of paper to its area, volume and surface area after it has been transformed into a cube.
- Geometric shapes: As students' progress through each of the lessons they will encounter numerous simple as well as complex geometric shapes. As students make their origami models they will produce: squares, equilateral triangles, cubes, pentagons, hexagons, pyramids polyhedrons and dodecahedrons.

Objectives

At the conclusion of this unit of study students will be able to use the process of origami in order to make paper models representing specific mathematical, chemical and biological concepts and processes. Specifically students will be able to:

- Read and follow a simple and basic origami diagram in order to produce a model
- Build 2-D and 3-D origami models depicting mathematical, chemical and biological models
- Understand how to use critical thinking skills to solve problems
- Use models to visualize a compound's chemical structure
- Demonstrate an understanding of DNA replication by building an origami model
- Demonstrate an understanding of how carbon is uniquely suited to form biological macromolecules by constructing molecular models of simple carbon compounds in particular the buckyball
- Identify how the techniques and processes used in origami are influencing, manufacturing, packaging, and shipping and other industries.
- Analyze relationships between two-dimensional and three-dimensional objects

Strategies

A variety of instructional strategies will be employed. One instructional aid that I suggest we employ is computer-aided instruction. Some students will need repetitive instruction in the process of origami. To this end we will use selected instructional videos. Students will have the choice of working independently, or in pairs to build their origami models. We will introduce origami by having students attempt a few of the classic or standard origami models such as the crane and the frog.

Whole Class Instruction: This method may be used to introduce both the science content, and the origami process. It is the oldest form of teaching, which is mostly lecture. We know it is very limited in its effectiveness. It is basically the most efficient way to transfer knowledge to a large group. We will use this method to explain concepts, provide core knowledge and direct student engagement particularly for model making. Lectures will be supplemented by using PowerPoint presentations, and YouTube videos.

Cooperative Learning: Cooperative learning is an instructional method in which students are placed into small heterogeneous groups to work together on a specific learning outcome. Students must work together to accomplish a task. This requires interaction and communication. It is believed that this interaction between students improves their learning and helps them with their interpersonal skills. Research has suggested that the use of cooperative learning significantly affects student's test scores in science.

Small Group Instruction: In a class of 31 high school students it is often difficult to just work with 4 or 5 students. However if you are able to have a number of students work independently and perhaps others working in cooperative groups you may be able to sit with a select group of students and give them direct instruction. This is when you might employ the "I do, We do, You do" method of instruction. This involves modeling the behaviors you want students to accomplish. Basically you will ask students to do as you do when attempting the folds and creases in the origami process.

Laptop Lab: Many students these days love doing assignments that require the use of electronics. We will make use of laptops as often as we can. Students will be directed to visit a certain web based tutorial sites for specific origami models.

Extended Reading and Writing: Extended reading and writing is an effort to give students an opportunity to continue their learning outside the classroom. It is more than homework; it is also taking their learning to the community and their households. Students will be given outside of the classroom research assignments and be encouraged to practice origami at home.

Lessons:

Lesson 1: Introduction to origami: Classic origami models known the world over

Lesson 2: Reading and following an origami diagram: Following an origami diagram and Newton's Laws of motion

Lesson 3: Making an origami cube: From a flat sheet of paper to a 3D model. Making a three dimensional polyhedron shaped like a box

Lesson 4: Making origami DNA: Creating the double helix

Lesson 5: Making an origami atom: Modular origami: Elements, atoms, and molecules

Lesson 6: Making an origami molecule: Modular origami: Atoms, molecules, and compounds

Lesson 7: Making an origami buckyball C_{60}: Modular origami, looking at carbon as a most special element

Lesson 1: Introduction to Origami modeling

Aim: At the completion of this lesson students will be able to read and follow an origami diagram in order to make an origami paper crane.

Materials and equipment: Either origami paper or copy paper folded and cut to measure 8 ½" by 8 ½". You will also need to either give students laptops or use your smart board to log onto the necessary instructional links.

Procedure: Log onto the following website to view the diagramming system. You may want to print the diagram. https://en.wikibooks.org/wiki/Origami/Techniques/Yoshizawa-Randlett_system#Operations

Direct Instruction: After reviewing the fold and crease diagram, practice folding. Either using modified copy paper or origami paper. If possible use origami paper that has a different color on each of its sides. Model the folding techniques with your students. As you model the origami process state clearly what you are doing, for example when making a valley fold, say so. It would be a good idea to review the entire Yoshizawa-Randlett system

Guided Practice: We are going to make a crane. Log on to the link below and access the Orizuru crane diagram by Andrew Hudson.
https://ahudsonorigami.files.wordpress.com/2011/11/tsuru.pdf

Independent Practice: Some students may have difficulty following the origami diagram or may benefit from viewing a step-by-step demonstration ("Beacon Learning Center Lesson Plans," n.d.). Log on to the following link.
https://www.youtube.com/watch?v=yTY-nGYYq_c

Check for Understanding: Ask students who were successful at making the crane to unfold it and count the number of folds and creases. How many mountain folds? How many valley folds?

Extended Reading and Writing: (1) Ask students to write a paragraph describing the sequence of folds and creases that it takes to make an origami crane? Bio connection: Ask students where would cranes most likely be found in the wild. What type of habitat is this? What other creatures might share the cranes' habitat? What do cranes eat?

Lesson 2

Aim: At the completion of this lesson students will be able to read and follow an origami diagram to make a moving frog. In addition students will explore Newton's third law of motion.

Materials and equipment: Materials and equipment: Either origami paper or copy paper folded and cut to measure 8 ½" by 8 ½". You will also need to either give students laptops or use your smart board to log onto the necessary instructional links.

Procedure: Log on to the following website to view the diagraming system. You may want to print the diagram. http://www.origami-fun.com/origami-jumping-frog.html

Direct Instruction: This website allows you to print the diagram out. You may want to do this or use your smart board for the entire class to view. Review each step in the process by having students read each step aloud as they do it. If at all possible you may want to build the frog along with students.

Guided Practice: Once again some students may have difficulty following the diagram and written instructions, if this is the case lets view a step-by-step demonstration. Log onto the following link. https://www.youtube.com/watch?v=pddCghMF5og

Independent Practice: Log onto the Origami-fun website and try the pelican. Scroll down the center until you see the pelican then click on it. http://www.origami-fun.com/origami-birds.html

Check for Understanding: Ask students to unfold one of their origami models and determine the number of folds that it took to make that particular model. After determining the number of folds, ask students, "How many times can you fold a sheet of paper?" In addition you may also want to ask students, what scientific principals are at play when you make the frog jump?

Extended Reading and Writing: Students will do a short research paper on the history of origami, its origins and popularity. Bio connection: What type of animal is a frog? What type of habitat would a frog live in? Physical science connection: Can you state Newton's law the corresponds to you making the frog jump? Can you make the frog jump different distances? How would you do that?

Lesson 3

Aim: Now that we have practiced making two of the classic origami models lets shift our attention to some mathematical and science orientated models. We will make an origami cube for the purpose of exploring the concept of density.

Materials and equipment: Materials and equipment: Either origami paper or 8.5" x 11" copy paper. You will need to either give students laptops or use your smart board to log onto the necessary instructional links. You will also need rulers and a scale.

Procedure: Have students measure and weigh the paper that they are going to use to make their model. Measure in grams and centimeters. Record these measurements. Log on to the following website to view step by step instructions for making the origami cube. https://www.wikihow.com/Fold-an-Origami-Cube

Direct Instruction: If possible make a cube along with your students. Once the cube is completed have students measure the sides of the cube they have constructed. Then have them weigh the cube. Have students record this information as well. At this time let's review the concept of density. Remind students that density is constant and is equal to mass divided by volume (D=m/V).

Guided Practice: Students should measure the length, width, and thickness of their origami or copy paper. Determining the thickness of the paper may be a challenge because it is so thin, persevere! Remind students that a cube is a three-dimensional shape that features all right angles and a height, width and depth that are all equal. Help students recall that Volume =L x W x H. Students are now ready to calculate the density of the flat sheet. After making this calculation, instruct students to calculate the volume of their cube. Remind them of the definition of a cube. Now calculate the volume of the cube. Instruct students to calculate the density of the cube. Compare the calculated density for the flat sheet with the calculated density of the folded sheet (cube). How do they compare? What might account for any differences if any, in the two calculations?

Independent Practice: Students who were successful at making the cube and doing the calculations have them compare their answers. If their answers differ, engage them in conversation as to what could attribute to the discrepancies in their answers?

Check for Understanding: Ask students if density is a physical property or chemical property? Ask students to explain in writing why there was or was not a change in density after the origami process was complete?

Extended Reading and Writing: Try making cubes of various sizes. Ask students to write a reflection statement on what difficulties they encountered trying to make the origami cube. Ask students to examine their cube and respond to the following:

How many faces does a cube have? How many vertices (points)? How many edges? Calculate the surface area of the cube, how does this differ from the surface area of the sheet of paper you folded into cube?

Lesson 4

Aim: We will be using origami to help reinforce concepts in the understanding of DNA.

Materials and equipment: Materials and equipment: Either origami paper or copy paper folded and cut to measure 8 ½” by 8 ½”. You will also need to either give students laptops or use your smart board to log onto the necessary instructional links.

Direct Instruction: Log on to the link. http://yourgenome.org/activities/orig... Scroll down to downloads and download the colored origami template. Hopefully you have access to a color printer, if not have students color the template.

Guided Practice: Either use your smart board or allow students the use of a laptop to tap the following link https://www.youtube.com/watch?v=0jOapfqVZlo

Independent Practice: Have students download this set of directions for the origami DNA model and attempt to follow these directions. Students may want to color their templates. Tap on to this link. http://biotech.bio5.org/sites/default/files/pdf/origami_inst.pdf

Check for Understanding: Biology is a Keystone tested subject so in this lesson we want to not only give students practice making origami models, but we want to reinforce some key biology concepts. Ask students when in the model making process do you start to see the Double Helix.

Extended Reading and Writing:

Log on the following link https://www.youtube.com/watch?v=pB0FMshudqE

After completing this model without referring to a textbook respond to the following questions. What is the structure of the DNA molecule? Describe in words what is a double helix. Ask students to write a reflection statement on difficulties encountered making the DNA origami model.

Lesson 5

Aim: To make an origami model of an atom of an element found on the periodic table.

Materials and equipment: Materials and equipment: Either origami paper or copy paper folded and cut to measure 8 ½” by 8 ½”. You will also need to either give students laptops or use your smart board to log onto the necessary instructional links.

Procedure: Either give students laptops or log on to the links using your smart board. It might be good for students to work in pairs or groups to build the origami atom.

Guided Practice: In order to build a molecule we must first make what is called the folding unit. Log on to the link https://www.youtube.com/watch?v=yyYphdC9f7E follow along as you view the step-by-step instruction. Make at least three folding units, as you will need them to make the atom. Now log on to this link for the step-by-step instructional video for instructions on how to build an atom. https://www.youtube.com/watch?v=SyH--QiOieo

Independent Practice: Allow students to review the YouTube videos as often as needed to make several atoms. Have student's research what colors are used to represent certain atoms and allow students to make different color atoms representing several elements.

Check for Understanding: After building origami atoms, ask students what is the shape called. Ask students why we would want to use different colors for atoms of different elements.

Extended Reading and Writing: Have students write a reflection statement on how their origami model compares to models of the atom depicted in their text. Ask students to speculate how they would link their origami atoms together to make molecules.

Lesson 6

Aim: To make origami diatomic molecules and compounds

Materials and equipment: Materials and equipment: Either origami paper or copy paper folded and cut to measure 8 ½" by 8 ½". You may want to use colored origami paper or have students color the paper themselves. You also need card stock for the connectors. You will also need to either give students laptops or use your smart board to log onto the necessary instructional links.

Procedure: Either give students laptops or log on to the links using your smart board. It might be good for students to work in pairs or groups to build the origami molecules.

Guided Practice: Engage students in conversation about atoms, molecules and compounds, with the intent of clearly defining each term, tap on to the following link which shows how to connect two atoms together horizontally https://www.youtube.com/watch?v=Pc7-aVMDbBE after viewing this step-by step instructional video tap onto this link to view haw to connect two atoms together vertically https://www.youtube.com/watch?v=9Q11nYeu4Wg

Independent Practice: Students should agree on what colors represent what elements and attempt to make molecules of some molecules and compounds. Start off simple like two red atoms connected would represent an oxygen molecule. A step further is to attempt to build a molecule of particular substance. For instance suppose we want to make an origami molecule of water. We would want to use blue to represent hydrogen and red to represent oxygen. Then connecting two blue origami atoms to one red origami atom, with the red atom in the middle, students have made an origami model of water, H_2O. Students can use their text to find a key of atom colors used in molecular models. Students may tap on this link for inspiration: https://www.youtube.com/watch?v=lUVSdXxZKnE

Extended Reading and Writing: Ask students to reflect on what difficulties they may have encountered trying to make this model. Ask students how do their origami models compare to the ball and stick models, and the cluster models that they commonly see?

Ask students to make the following diatomic molecules using the following colors: Oxygen, O_2 (red), Hydrogen, H_2 (blue), Chlorine, Cl_2 (green). After making several diatomic molecules lets try a few more challenging molecules: Phosphorus, P_4 (gold or brown), Sulfur, S_8 (yellow).

Lesson 7

Aim: To make a model of the C_{60} molecule commonly called carbon buckyball (Buckminsterfullerene).

Materials and equipment: Materials and equipment: Either origami paper or copy paper folded and cut to measure 3" x 3" squares. You may also want to use assorted colors. You will also need to either give students laptops or use your smart board to log onto the necessary instructional links.

Procedure: Either give students laptops or log on to the links using your smart board. It might be good for students to work in pairs or groups to build the

Guided Practice: Share with students that carbon atoms have the ability to form molecule chains thousands of atoms long. To build this model we will make a building unit, which is called the PHiZZ unit (Pentagon Hexagon Zig-Zag). These units will be connected together to form an origami C_{60} molecule (carbon buckyball). Let's start with making the PHiZZ unit: Click on to this link for step-by-step instructions https://www.youtube.com/watch?v=vFYw47Wx2N8

Log on to part 2: https://www.youtube.com/watch?v=dH-uTRdI4XU

After students have made their PHiZZ units they are ready to make a buckyball. Click onto this link for step-by step instructions on how to make the buckyball, https://www.youtube.com/watch?v=9GmSkfBt8fo

Log on to part 2: https://www.youtube.com/watch?v=lUN4XX1zUw0

Independent Practice: An alternative to making the origami buckyball with PHiZZ units is to make the buckyball with 60 uncut equilateral triangles. Click onto this link for step-by-step instructions. First, we must make our triangles: Tap on the link. https://www.youtube.com/watch?v=KDjQbL__Srw After making your triangles Tap onto this link https://www.youtube.com/watch?v=n2c27X6y4CI Students may want to access this link as well. It takes a different approach to the tutorial https://www.youtube.com/watch?v=1KMkKKjS9Cw

Extended Reading and Writing: These instructional videos contained a number of math terms. Without looking in the text write definitions for the following terms:

Horizontal… Vertical… Diagonal… Pentagon… Hexagon… Pyramid… Vertex… Truncated icosahedron

Students who have attempted both methods of making the buckyball ask them which method do they prefer.

As an enrichment assignment have students research C_{60} also known as Buckminsterfullerene. In their research they should discuss how it is formed in nature and why.

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Appendix: Standards

PA: 3.4.12.A: Apply concepts about the structure and properties of matter

BIO.B.1.2.1: Describe how the process of DNA replication results in the transmission and or conservation of genetic information.

BIO.B.2.2.1: Explain how carbon is uniquely suited to form biological macromolecules.

BIO.B.2.3.1 Describe how genetic mutations alter the DNA sequence and may or not affect phenotype.

CHEM.A.2.1.1: Describe the evolution of atomic theory leading to the current model of the atom based on the works of Dalton, Thomson, Rutherford, and Bohr.

CHEM: B.1.2.2.2: Apply the law of definite proportions to the classification of elements and compounds as pure substances.

CHEM.B.3.1: Explain how atoms combine to form compounds through ionic and covalent bonding.

CHEM.B.1.3.2: Classify a bond as being either polar covalent, non-polar covalent or ionic.

CHEM.B.1.4.1 Recognize and describe different types of models that can be used to illustrate the bonds that hold atoms together in a compound (e.g., computer models, ball-and-stick models, graphical models, solid-sphere models, structural formulas, skeletal formulas, Lewis dot structures)

PA Core Standards: 9-10

Reading in Science and Technical Subjects:

3.5 Reading Informational Text: Students read, understand and respond to informational-text – with emphasis on making connections among ideas and between text with focus on textual evidence.

CC.3.5.9-10.C Follow precisely a complex multistep procedure when carrying out experiments, taking measurements or performing technical tasks and attending to special cases or exceptions defined in the text.

CC.3.5.9-D. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 9-10 texts and topics*.

SAS Standards:

Science and Technology and Engineering Education

3.1: Biological Sciences:

3.1.C.B3. Describe the structure of the DNA and RNA molecules

3.1.C.B5 Use models to demonstrate patterns in biomacromolecules.

3.2: Physical Science and Chemistry

3.2.C.A.1 Differentiate between physical properties and chemical properties

3.2.10.A2 Compare and contrast different bond types that result in the formation of molecules and compounds