**Technology, Engineering and Design**

**Manufacturing Primer**

**John Scarfpin**

**Aerospace Manufacturing in the Classroom**

Airplane manufacturing has many unique requirements that can easily be adapted to the classroom setting. The set of job skills required in Aerospace manufacturing involve Science, Technology, Engineering and Mathematics at almost every phase. This lesson is purposefully designed to address specific math skills used daily from the Aerospace manufacturing point of view that also flow over into many other technical and scientific fields of study.

**Introduction**

Students will be working on math lessons that involve measurement, unit conversion, dimensional analysis, and percent error calculations. These skills are used routinely in manufacturing on a daily basis. Frequently, workers are required to convert from metric to standard measurements depending on customer specifications. In order to stay within tolerance levels manufacturers must be able to cut, fit, and affix parts with a high level of accuracy. This lesson functions as an engineering primer. Regardless of what your students will be building this lesson will take them through measurement, cutting, and assembling a low cost model. This will allow you to see what the students’ skills are like before turning them loose on a more expensive building project.

**Learning Outcomes**

* Students will learn to measure and cut accurately
* Students will explain the difference between precision and accuracy
* Students will create a prototype by folding an origami cube and sketching it in their notebooks with accurate measurements
* Student will analyze their sketch and prototype to create a materials estimate for a finished product
* Students will accurately cut all members needed to construct a cube from balsa wood.
* Students will work in teams of two to create the final product within specification
* Students will create an analysis of their process and finished product including Percent error calculations on the cut lengths of members, determining if the final product is within specification, and determining the interior volume of their final product.

**Curriculum Alignment**

**Common Core Math**

7.RP.2 . Recognize and represent proportional relationships between quantities.

a. Decide whether two quantities are in a proportional relationship

c. Represent proportional relationships by equations.

7.G.1 Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale

7.G.2 Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions

**Technology, Engineering and Design 8210 Blueprint (Design)**

Students will learn to:

* Use prototypes and models to ensure quality, efficiency, and productivity of their final product
* Distinguish the criteria and constraints and reflect on how the criteria and constraints affected the final solution
* Analyze properties and determine attributes of two and three dimensional objects.
* Communicate their observations, processes, and results of the entire design process and the final solution, using appropriate verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

**Classroom Time Required**

Six to ten days of 45 minute classes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Day 1** | **Day 2** | **Day 3** | **Day 4** | **Day 5** | **Assessment** |
| **Presentation** | Pre-assessment  Measuring in standard and metric with a ruler. | Dimensional Analysis and Changing Units | Precision and Accuracy  Percent error calculations | Significant Figures  Review Measures of central tendency | Performance Assessment – Students will complete the assembly of their cube. | Cumulative Assessment – Compile the formative assessment questions used from the question bank to create your own. |
| **Activity** | Origami Cube | Measurement worksheet | Percent Error Calculation of cut parts | Precision and Accuracy worksheet | Assemble and glue the cube. Outside tolerance is ±0.1 cm |  |
| **Skills Assessment** | Cut a 8.5 inch square from paper | Materials Estimate - Determining total length of wood in centimeters to complete a cube with diagonal supports | Create Cube Edges - Cut 6 Sticks to 5.5 cm ±0.1 | Create Supports - Find length of diagonals and cut 6 of them | Determine the interior volume of the cube | Check the final assembly for square angles and that it fits within tolerance for being a cube. |
| **Available Review Materials** | Measurement videos – Using a ruler and Metric Measurement | Khan Academy  -Unit Conversion  -Perimeter with unit conversion |  | Khan Academy  Multiplying and Dividing Significant Figures | Volume with units |  |
| **Formative Assessments** | How many “x units” are in one “y units”? | Pythagorean Theorem | Percent Error | Significant Figures | Volume of a cube |  |

**Materials Needed (Required)**

* Hobby Knife or Balsa Wood Cutter (At least one to every two students)
  + *Management Tip – Drill a grid of holes in a block of wood that the handle of the knife fits into and number each knife so you can verify who has it and that it is returned at the end of each class.*
* Cutting mat or cutting board – *Self healing mats are nice but expensive. If you are working on a budget buy a sheet of 4’x8’ shower board ($16) and cut it into 12”x12” pieces to make a cheap set of whiteboards and use the back for a cutting board.*
* Wood Glue
* 1/8”x1/8”x36” Balsa Wood (One stick for every student at about $0.14 each if bought online)
* Measurement tools (Class Set or One to every two students)
  + Metric and Standard ruler
  + Meter Stick
  + Protractor
  + Paper
  + Scissors
  + Measurement and Conversion worksheet
  + Ball
  + Rectangular solid
  + Cylinder
  + Spring
  + Calculator

**Technology Resources (Recommended)**

* Computer with Internet Access (At least one to every two students)
* Internet Access
* Headphones (Class Set)
* File hosting tool such as Moodle or a Wiki
* Google Forms (See Teacher Videos)
* Floobaru Script (See Teacher Videos)

**Pre-activities (Recommended)**

Review fractions and using a ruler prior to beginning this unit. I have included videos on using a ruler and videos on fractions can be found at KhanAcademy.com.

***Teacher Preparation***

Before beginning this lesson the teacher should setup a Moodle or Wiki page to house all the videos and files associated with this lesson. All links should be checked to ensure they will pass through your schools Internet filter. The teacher should view all videos and work through all activities prior to implementing them in the classroom to gain a thorough understanding of what is being asked of the students. Other suggested preparation activities include:

* Setup toolboxes with measurement instruments and materials to be measured
* Springs from dead mechanical pencils and pens
* Cylinders cut from dowel rod
* Rectangular solids from high school wood shop scrap box
* Spheres – marbles from the dollar store
* Create formative assessments in Google Forms (See Teacher Videos)
* Install Floobaru as a script file for Google Forms. Enter the correct answers as user name Answer Key. Floobaru will then grade all the responses according to Answer Key. This allows for easy grading and quick feedback to students. (See Teacher videos)

***Student Preparation***

Review integers, fractions, and common units of measurement. Students should know common relationships in measurement; 12 inches to 1 foot, 36 inches to 1 yard, 5280 feet to 1 mile, 16oz to 1 lb. In the pre-assessment students will create a list of all the common measurements they know and categorize them to assess prior knowledge.

**Activities**

**Day 1**

**Rationale**

Students will be measuring and cutting a square that will be folded into a cube. This cube will become the prototype for this week’s product. The students will be taking measurements from the prototype and sketching it in their notebooks with the measurements they find. The students should measure and sketch with inches. This will be used in the upcoming lessons.

**Pre-assessment**

Have students write as many units of measure they can in three minutes and then have classify the measurements into the following categories: Length, Area, Volume, Time, Rates, Weight/Mass, and Energy. Discuss with the class common measurements they may have left out.

**Presentation**

Review with the students how to use a ruler and read the line segments on the ruler. If you have a document camera, use a ruler and a sharp pencil to demonstrate how to read the ruler. If you do not, find a picture of a ruler that can be displayed on the board to demonstrate how to read a ruler.

**Activity**

Each student will need:

* Paper
* Rulers
* Scissors

Instruct the students to measure and cut an 8.5 inch square from the paper. Have students raise their hand when they are done so they can be checked off for the Skills Assessment. As you check them off for cutting a 8.5 inch square provide them with the instructions for folding the Origami Cube. Upon completion of the paper cube have students sketch the cube in their notebooks with measurements in inches.

**Skills Assessment** –The skills assessment is quick check of whether or not the student can apply the skill they are supposed to learn.

Check that the student has measured properly and has in fact created a square when they cut out the 8.5” piece of paper. The more accurate they are at creating a square the better it is for the origami project. Check at the end that the students have sketched their cubes in their notebooks with measurements in inches.

**Review Materials**

Videos “Using a ruler” and “Metric measurement”

**Day 2**

**Rationale**

This lesson is designed to give students experience measuring a variety of different shapes and being able to convert measurement systems.

**Presentation**

Dimensional Analysis PowerPoint

**Activity**

Students will be measuring objects, recording their measurements in inches and then converting them to centimeters.

Students will need:

* Measurement and Conversion worksheet
* Ball
* Rectangular solid
* Cylinder
* Spring
* Ruler
* Calculator

To reduce the amount of materials required you may choose to have students complete this activity in groups of two.

**Skills Assessment**

Have students refer to the sketch from day one. The students will need to convert from inches to cm from their drawings. Then have them determine the length of wood required to construct a cube. They need to add up all of the edges and diagonals of the cube.

**Review Materials**

If a student is still unclear on unit conversion they can view the following video from Khan Academy

<http://www.khanacademy.org/math/algebra/ratios-proportions/v/unit-conversion-with-fractions>

**Day 3**

**Rationale**

This lesson runs together with Day 4 in developing the concepts of Precision and Accuracy. This is only intended to be an introduction to precision and accuracy.

**Presentation**

Precision and Accuracy PowerPoint – this power point introduces students to precision and accuracy and percent error calculations

**Activity**

Students will need:

* 1/8 x1/8 x 36 inch balsa stick’
* Hobby knife or wood cutting device
* Ruler
* Ziplock bag

Students will begin cutting wood for their cube construction. They need to cut six pieces to 5.5 cm. Upon completion of cutting all six pieces they need to re-measure and record the exact length of the cut pieces in their notebook. They will then do a percent error calculation of the parts. The acceptable tolerance is 5.5 ± 0.1 cm. The cut pieces will be stored in the Ziplock bag until they are needed in the construction process.

**Skills Assessment**

Check that all six of the pieces cut are with in tolerance. Have the students calculate the length of the diagonal lengths of the cube. Have them verify this by drawing a right isosceles triangle with 5.5 cm bases. The number generated by the Pythagorean Theorem will be the length of the hypotenuse if it really is a right triangle. This triangle will serve as an angle cutting guide later.

**Day 4**

**Rationale**

Students need to understand the concepts of precision and accuracy as they relate to engineering and manufacturing processes. Results must be both accurate and precise with every duplicate made in industry. Every project has its’ own set of tolerances and specifications and designers are required to function within them. This lesson is designed for middle school students so for many of the students this is the first time being exposed to this type of material. By no means are they expected to master this information this is only designed to familiarize them with an idea that will be reinforced in a high school Chemistry or Physics class.

**Presentation**

Significant Figures PowerPoint - this presentation covers basics of significant figures and reviews measures of central tendency.

**Activity**

Students will need:

* Precision and Accuracy Worksheet
* Calculator

**Skills Assessment**

Cut six pieces of wood to the length calculated in yesterday’s skills assessment (approximately 7 cm).

**Available Review materials**

Khan Academy Adding, subtracting, multiplying and dividing with significant figures

<http://www.khanacademy.org/math/algebra/exponents-radicals/v/addition-and-subtraction-with-significant-figures>

<https://www.khanacademy.org/math/arithmetic/decimals/significant_figures_tutorial/v/multiplying-and-dividing-with-significant-figures>

**Day 5**

**Rationale**

Today everything comes together. Students will work in pairs to complete a cube. Each student only has enough material to do half of a cube and they must merge their pieces. If they have cut accurately they should have a cube with nice square edges.

**Presentation**

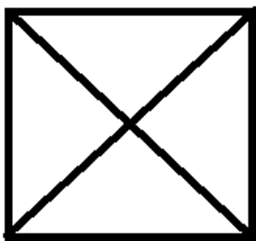
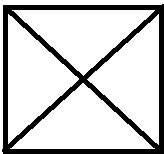
**Activity**

Students will compare their percent error calculations on the cut pieces they created. They will then trim and cut angles as they build and glue their cubes.

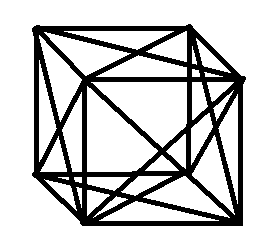
Students will need:

* 45-45-90 Triangle they drew earlier in the week
* Balsa sticks cut to length
* Wood glue
* Masking tape
* Cutting board
* Hobby knife

Students should construct two squares with diagonals in place flat on the cutting board. The diagonal supports need to be in the same plane so one will have to be cut in half and glued in place. These will be the top and bottom of the cube.



They need to verify these are 5.5 cm squares at this point. Next they need to cut the joining members to length to ensure a 5.5 cm height. The diagonals will help in ensuring a square side if they are cut to an accurate length.



**Skills Assessment**

Upon completion of the cube it should measure 5.5 cm along all edges. Excess wood glue can be sanded from the faces to improve the aesthetics of the final product. Students will need to measure the interior and calculate the internal volume of their cube.

**Available Review materials**

Khan Academy Volume with units

<https://www.khanacademy.org/math/arithmetic/rates-and-ratios/unit_conversion/v/solving-application-problems-involving-units-of-volume>

**Assessments**

**Formative Assesssment**

Student will be assessed through daily Skills Assessments by accurately measuring physical objects and creating cutouts and or sketches with accurate dimension. Students will complete class exercises and investigations in measurement, conversion and percent error measurement. The class will use Google forms to take daily quizzes (formative assessments) on objectives. You will have to create your own formative assessments in Google Forms based on what you want to focus on. I have provided a question bank with suggested questions for each activity. Install the Floobaru script in your Google Form and it will grade the quizzes for you. I have included Teacher videos that show how to create and quiz and how to install and use Floobaru script.

**Summative Assessment**

The summative assessment will be derived from question bank used for the daily quizzes (formative assessments) given through Google Forms. You will have to create your own test based on previously selected questions for your students. This too can be done through Google Forms and you will have to install the Floobaru Script again.

**Supplemental Information (Optional)**

*Supplemental information is anything that teachers should or might consider when teaching this lesson. These are resources that may be used but that are not required for the lesson.*

Supplemental information and resources for this lesson include:

* Create parts in a CAD program and introduce students to processes involving CNC or other types of machining may be outsourced to existing partnerships such as community colleges. Advanced manufacturing programs are growing quickly at community colleges across the state and are willing to help with projects for K-12 schools.
* Materials do not have to be of the type or size as those indicated, teacher may alter with appropriate materials
* Assign students to watch videos at home prior to using them in the next day’s class. Khan Academy is a great resource if you do not have time to go back and reteach concepts students should know. Do not make them do it on their own though. Follow up with students after they have watched the videos so you can answer specific questions about things they do not understand.

**Critical Vocabulary**

Conversion factor

Dimensional Analysis

Accuracy

Precision

Unit (as related to volume, weight, and measure)

Significant digit/figure

Proportion

Ratio

Percent Error

Diameter

Radius

Circumference

Perimeter

**Websites**

Students can get more information and practice as math is fun using the following url:

[**http://www.mathsisfun.com/measure/us-standard-length.html**](http://www.mathsisfun.com/measure/us-standard-length.html)

**Dimensional analysis is fun -** this website has several examples of the use of dimensional analysis and provides through explanation of each.[**http://www.alysion.org/dimensional/fun.htm**](http://www.alysion.org/dimensional/fun.htm)

**MIT dimensional analysis pdf (Teacher Document)** - This is a teacher resource from MIT. It is basically a book and goes into the how and why of dimensional analysis. It is far above what a middle schooler should know but is great resource for expanding the teachers understanding.[**http://web.mit.edu/2.25/www/pdf/DA\_unified.pdf**](http://web.mit.edu/2.25/www/pdf/DA_unified.pdf)

**Khan Academy** - There are several videos on significant figures and calculating using significant figures here.

* Significant Figures <http://www.khanacademy.org/math/algebra/exponents-radicals/v/significant-figures>
* More Significant Figures
* <http://www.khanacademy.org/math/algebra/exponents-radicals/v/more-on-significant-figures>
* Adding and subtracting with significant figures
* <http://www.khanacademy.org/math/algebra/exponents-radicals/v/addition-and-subtraction-with-significant-figures>
* Multiplying and dividing with significant figures
* <https://www.khanacademy.org/math/arithmetic/decimals/significant_figures_tutorial/v/multiplying-and-dividing-with-significant-figures>
* Unit Conversion
* <http://www.khanacademy.org/math/algebra/ratios-proportions/v/unit-conversion-with-fractions>
* <https://www.khanacademy.org/math/arithmetic/rates-and-ratios/unit_conversion/v/perimeter-and-unit-conversion>
* <https://www.khanacademy.org/math/arithmetic/rates-and-ratios/unit_conversion/v/solving-application-problems-involving-units-of-volume>

**Author Info**

**John Scarfpin**

* West Craven Middle School (6-8), Craven County School System
* I am the STEM teacher for West Craven Middle School operating under the CTE department teaching “Technology, Engineering and Design”
* I am licensed in Math, Science, and Technology Education
* I have a B.S. in Education with a specialization in Math and Science from Ohio University and am currently working on a Ma.Ed in Instructional Technology Systems at UNCC (Complete 12/2013)
* I am interested in global education systems and have participated in the Fulbright Japan teacher exchange program for Education for Sustainable Development

Special thanks to Kenny McNeil who helped me with the original conception of this lesson as we worked together in the Kenan Fellowship at Spirit Aerosystems.