**Design For Manufacturability Activity**

**Objective**

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| **Objectives**  1.) Develop an understanding of the IME Design For Manufacturability concept.  2.) Apply creative thinking to increase manufacturability for a real world example.  3.) Understand how to cut costs while maintaining function and quality when designing a product.  4.) Develop an understanding of the importance of Design For Manufacturability and its applications. |

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| **Skill Level:** This activity is targeted for middle school age and knowledge level. | **Prep time:** 20 min per group of students **Class time:** Approximately 50 minutes |

**Materials**

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| * 1 Lego Creator kit #6912 per group of 4-5 students. * 1 printout of the DFM Activity sheet per group of 4-5 students * 1 Ziploc bag per group of 4-5 students. |

**Standards**

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| **Disciplinary Core Idea:** ETS1.C: Optimizing the Design Solution  **Performance Expectations:**  MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.  MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. | |
| **Practices** Asking questions / defining problems Developing / using models Planning / carrying out investigations Analyzing / interpreting data Math / computational thinking Constructing explanations / design solutions Engaging in argument from evidence Obtaining / evaluate / communicate | **Crosscutting Concepts**  Short/Long term Consequences  Positive/Negative Consequences  Society Driven Technology Systems and system models |

**Background Information**

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| **Introduction:**  **Design For Manufacturability** (DFM) is the focal point of manufacturing engineering. DFM refers to the process of designing products in a way that seeks to reduce costs and utilizes current manufacturing processes and capabilities. In the simplest form DFM is simply manufacturing a product in the simplest and easiest way possible.  **Background Information:**  Design For Manufacturability is an important concept because it is of critical importance to link the design of a product to the way that it is made. Design engineers are responsible for creating and designing products that meet the goals of a project. They must be keenly aware when designing of how a specific product can be made. If they do not know the capabilities of their manufacturing facility or company they run the risk of designing a product that cannot be easily, or cost effectively made. In companies today this link between manufacturing and design engineering is still a struggle.  Manufacturing engineers attempt to bridge this gap by using the concept of DFM. They try to provide the link between ideal designs and what is actually possible to create. Manufacturing engineers are experts when it comes to machinery and process design. By understanding the limits of what equipment is available, manufacturing engineers attempt to work with design engineers to come up with a product design that meets the needs of the customer or requirements, but that is also easily made with current technology and machine capabilities.  In designing for manufacturability, costs of production are greatly reduced. If products are designed with manufacturing capabilities in mind from the start, problems are caught early in the design phase, rather than later on. For example, welding certain metals together can actually weaken the mechanical properties of the material, which could be an unintended result of manufacturing easily overlooked by design engineers. Potential manufacturing problems should be highlighted before a design concept is fully finished. If a product was designed without awareness for how it is to be made, that product could make it all the way to production before a manufacturing issue was discovered. The time and cost to catch a problem during manufacturing is far greater than in the design phase because the design must be re-evaluated and the production tools must be altered to accommodate this change. This cost could be greatly reduced by simply considering manufacturing processes before the design is completed.  Traditionally, design engineers and manufacturing engineers worked independently of one another. The design engineers would create a design and hand it off to manufacturing to figure out how to make it. This type of design and manufacturing is referred to as **over the wall engineering**. See image below for illustration.    *Figure 1: Over the wall engineering.*  Designs in over the wall engineering are only evaluated for manufacturability after the design has been completed and is handed off to the manufacturing department. As can be seen from the above image, a lot of confusion can occur over how to produce a product that has not been designed with manufacturability in mind. Some of the problems associated with this approach include time and cost delays. It takes a much longer time to design a manufacturing process around a product that has been designed with no specific manufacturing process in mind. This in turn costs the company money because they cannot make a profit on products until they have been manufactured and sold to customers.  The time between a complete design and a fully functioning product is called **Time-to-Market**. Time to market is the duration it takes a company from the initial design phase until it reaches the consumer. Time to market is much higher for products that are designed independently of a company’s manufacturing capabilities. In real situations time to market can be of critical importance to the profitability of a company. Take for example a high technology company such as Apple. If they use an over the wall approach to product design, the time to market will be significantly long. Apple relies heavily on innovation and makes the most money when they release cutting edge technologies ahead of their competitors. Severe financial and market share consequences occur if Apple is unable to stay ahead of their competition in the speed in which they release new products. Apple will be more successful if they are able to be the first in their category in releasing new products.  If design engineers and manufacturing engineers work together to create a product, a lot of expensive redesigning can be avoided upfront. This type of engineering is called **concurrent engineering**. Concurrent engineering simply means that product and manufacturing process designs are completed in parallel and in conjunction. If a product is to be created that requires a new manufacturing technique, the product design and the manufacturing process development occur in unison. Prototype designs are utilized to test new manufacturing methods, and designs are modified based on feedback from the prototype production.    *Image 2: Concurrent Engineering*  Concurrent engineering takes place in a team atmosphere. Design engineers are paired with manufacturing engineers and process specialists. Design alternatives are evaluated based on manufacturing ease, cost, and time to implement. Many times, concurrent engineering leads to effective designs that end up much simpler than the initial design. This increases the speed to market, improves quality, and reduces production costs. Concurrent engineering teams try to avoid reinventing the wheel with every new product. They try to use known processes and designs from similar products and apply those to the new product. Since a product’s design is not set in stone when the team evaluates it, it gives the concurrent engineering design team the opportunity to reduce the complexity of the design and apply similar product manufacturing techniques to the concept.  With manufacturing processes in mind, many teams try to reduce the amount of individual parts needed to create a new product. They try to design **interchangeable parts** that can be used in many places on a product. Interchangeable parts are parts that can be used in multiple different products. By keeping the individual part quantity low, fewer manufacturing processes must be developed. Additionally symmetry is used in designs so that left and right sides of products use the same parts, again reducing the quantity of individual parts.  Concurrent engineering teams are also concerned with **product simplification**. By finding alternatives to designs that use existing parts, or that make use of simpler manufacturing techniques, companies can save a significant amount of money as well as increasing their speed to market. Components of a design that can be engineered to make use of existing parts can save process design time and also eliminate any unknowns about the manufacturability of that specific component. By revising the amount of parts needed and simplifying overall designs, production costs are greatly reduced. |

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| **Engage** |
| You work for a company that produces airplanes that are having difficulty selling because the price is too high. Customers like the product, but are unwilling to pay the asking price. What can you do to reduce the price of the product without reducing the functionality? Can some of the more expensive features be removed to lower the price? Would increasing the speed of manufacturing lower the cost of the product? |

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| **Explore** |
| Students will be challenged to create a simple airplane that uses less parts and costs less.  For each Lego kit the airplane (Super Soarer), needs to be built prior to this activity. If they are not built before the start of the activity, it will result in the lesson taking more than 50 minutes to complete.  The object of this assignment is to simplify a product to make it easier to manufacture. Our product uses the Super Soarer (airplane) from the provided Lego kits. The main way to make the Lego airplane easier to manufacture is to reduce the number of parts required. Each color of Lego is assigned a price. Every time a Lego of a certain color is removed, it correlates to the assigned amount of cost subtracted from the total airplane cost. The price of the original airplane built with the provided instructions in the Lego kit will be valued at $800. The students will remove some of the nonessential Lego pieces to make a simpler airplane. At the end of the activity, the students will calculate the total price of their new and simplified airplane. The new total price will be divided by the old total price and subtracted from one (1). This will give the total percent reduction in cost between the original airplane and the simplified airplane.  Original Plane Cost: $800    **Procedure:**  1. Get into groups of 4 or 5 students.  2. Each group of students should get a prebuilt Super Soarer (airplane) from the kit. The extra Legos from the kit are not needed in this activity. Students must be careful not to destroy the airplane before the activity.  3. Each group of students should get a paper with a list of the rules and the prices for the Legos.  Essential Design Criteria:   * Plane must have two rear wheels, one front wheel * Plane must look like an airplane, and be able to function like an airplane with two main wings, two rear wings and an upright wing in the rear * The pointed nose cone must be at the front of the airplane. * Plane must be symmetrical (same pieces on each side) * Must have a cockpit window   4. One student is the designated person to record what comes off the plane. This is done by the color of the removed Lego piece.  5. Once all the material is handed out, the students can begin trying to simplify the airplane. They should only remove the Lego pieces that will not affect the functionality of the airplane. Students are allowed to redesign the airplane as much as they want as long as the rules are followed.  6. The students are to work on this activity for 20 minutes.  7. As Lego pieces are removed, they should be placed in some kind of container to avoid getting lost (A Ziploc bag will suffice)  8. After the allowed time is completed, each group should calculate the cost reduction percentage between the original airplane and the newly designed airplane. This is the sum of the costs for the Legos removed divided by the original cost ($800) and then multiplied by 100 to make it a percentage.  9. Each group should be asked to share about what pieces they took off of the product and why, as well as what reduction percentage of cost they saved the airplane manufacturer.  10. (Optional) Students should also present and discuss how they utilized all of the members of the group to arrive at their final product, or how they worked as a team during this activity.  11. All Legos should be cleaned up and placed in a container or bag.  12. Lead group discussion. |

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| **Explain** |
| 1. Were all of the blue Legos were vitally important to the function of the airplane? If they were, would this make the activity harder and more difficult to reduce cost? What about the yellow Legos?  A: No, most of blue Legos were used for cosmetic purposes and easy to remove for this activity. If they were vitally important and could not be removed, the activity would be more difficult due to the fact that there would be less pieces to remove. The yellow Legos were more structural in the design of the airplane and were more difficult to remove when compared to most of the blue Legos.  2. In this activity, how were the groups able to reduce time to market?  A: The teams that finished the redesign of the airplane earliest were the first to market. One of the ways was to work quickly to simplify the plane. Each group would have treated every other group as their competitor. It is important to note that speed is not the only goal, the group that is first to market still has to have made the correct design and manufacturing decisions.  3. What are some pros and cons of having a slow time to market?  A. Some of the slower teams may have had a higher cost reduction percentage (pro), but they missed out on the initial customer base (con) that the team that was first to market enjoyed (think about the iPod). If the teams that were slow to market have a high cost reduction percentage, then they can sell the product for less money or a higher profit (pro), but will have more competition (con). |

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| **Elaborate** |
| **Experiment Questions**:  1. What element of this activity would change if we were trying to be the first to market?  A: The activity would be a race between teams. The first team to market would reach more customers because of little competition. However, the team to reduce the cost the most would also be desired because customers will buy a lower priced product. There is a balance between the speed to reach the market and the higher quality of the product.  2. Using these exact same Lego pieces, what other products could be made?  A: Numerous answers. A helicopter or a boat are examples. The benefit of using the same pieces of Legos is that no other materials are required. If a company can make multiple products out of the same selection of parts, then the inventory costs and complexity of the products are drastically reduced. This is the concept of interchangeable parts. This same activity can be completed on different products. |

**Resources**

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| **Additional Resources:**    <http://www.design4manufacturability.com/DFM_article.htm>  <http://www.unm.edu/~bgreen/ME101/dfm.pdf>  **Resources Used:**  An activity sheet is provided for the students to use during this activity.  A presentation is provided to aid instruction for this lesson. |