**IE Facility Design Activity**

**Objective**

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| **Objectives**  1.) Understand and implement facility design principle of reduction of travel waste.  2.) Apply creativity and facility design to a real world application.  3.) Be introduced to transportation and motion waste in manufacturing. |

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| **Skill Level:** This activity is targeted for middle school age level. | **Prep time:** 30 minutes **Class time:** Approximately 50 minutes |

**Materials**

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| * 1 Lego creator kit per team of 4-5 students. * 1 11x17 Zoo grid board per group of 4-5 students. * 1 Layout rules sheet per group of 4-5 students * 1 set of markers per group - yellow, light gray, dark grey, black, blue * 1 set of Guidelines per group of 4-5 students. |

**Standards**

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| **Disciplinary Core Idea:**  ETS1.A: Defining and Delimiting Engineering Problems  ETS1.B: Developing Possible SolutionsETS1.C: Optimizing the Design Solution  **Performance Expectations:**  MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.  MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. | |
| **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:**  Industrial Engineers (IE’s) use their skills and knowledge of processes and improvement design to develop facility layouts in the most efficient way possible. IE’s do this because they are trained to study processes, including time and motion studies. When motions can be reduced when manufacturing products, time is saved. When time is reduced in the manufacturing process, money is saved. Facility design involves the coordination of machines, personnel, products and transportation arranged in the best possible manner to support the function of the facility. In the manufacturing world, a facility could range from a production factory to a shipping warehouse and everything in between. Facility design principles can also be applied to many applications outside of manufacturing as well. Package and mail delivery routes are optimized by picking the best overall route to shorten travel distance as well as reduce delivery time. Supermarkets are laid out and organized by shelving in a specific manner to attract customers and to group similar products together. Each of these examples shows how the function of the facility or environment is identified and the layout of each component is optimized to meet that function.  **Background Information:**  When engineers develop or analyze a process for improvement they are concerned with making it as efficient and effective as possible. In order to be able to do this, processes must be measured on different criteria in order to make sound judgments in their development. Engineers look to waste as a way to measure how efficient and effective a process really is. Waste is a broad term that is defined as anything that does not add value to a product or service. Industrial engineers separate waste into seven main categories shown below.    *Figure 1: 7 Wastes of Manufacturing*  The categorizations above each apply to different aspects of manufacturing. These same types of waste can be seen in applications outside of manufacturing as well. The list below provides a short explanation of each type of waste.   * Defects: Defects are any unplanned imperfections, blemishes, or general errors that are caused during a manufacturing process. Defects cause a product or service to have to be redone or reworked. Outside the manufacturing of products, defects can exist in many places. For example, a mail delivery man delivers a piece of mail to the wrong address. This is a form of defect which causes the delivery process to be repeated. * Overproduction: Overproduction in its simplest form means to create more than is required. The definition can also be expanded to include redundant work, doing tasks more times than necessary. Overproduction also is a waste that is evident in the same mail carrier example listed before. In this case overproduction, could mean that the mail carrier returns to the same house more than once during a day to deliver mail. * Transportation: Transportation waste is moving parts or product around a facility unnecessarily. This also includes moving inventory out of the way to find a specific part or product. For a mail carrier shuffling through an unsorted pile of mail to find the mail that needs to be delivered could be called transportation waste. Another example is long distance mail delivery. Mail could be delivered to its destination through a series of mail carrier exchanges. The route of the mail to be delivered could follow a path that is not the quickest straight line path to the destination. * Waiting: Waiting is simply idle time that occurs between processes, a product may sit in queue waiting to be worked on while a machine or operator is busy. Waiting time does not add value to the product or service, making it a type of waste. Again, outside of manufacturing, waiting waste occurs in the route that a mail carrier takes to deliver mail. If the route has heavy traffic, the mail carrier may have idle time waiting in that traffic. In a minor form mail carriers that are delivering packages may experience waiting when hand delivering packages. They must wait idle for the homeowner to open the door after ringing the doorbell. During this time, the mail carrier is idle. * Inventory: Inventory waste is having too much product, or materials on hand then can readily be used. Excessive inventory is classified as waste because it takes up space that could be used more productively. Inventory also costs money, either to make the inventory or to buy it. In sticking with our mail carrier example, inventory waste occurs in the amount of mail that is stored on a truck to be delivered. Mail carriers with more packages on board than can be delivered that day experience waste. The additional weight can decrease fuel economy and raise costs. Additionally the excessive inventory becomes cumbersome and leads to other wastes including overproduction and transportation. * Motion: Motion waste includes any movement by a person or machine that does not add value to a product or service. Motion wastes are most easily seen by comparing the actions of one person to another. They could be doing the same job but going about it different ways, one faster than the other. A mail carrier exhibits motion waste when delivering mail from a truck to multiple houses on foot. The mail carrier could choose to walk mail to the first house, then return to the truck to retrieve mail for the next house. A more efficient solution could be for the mail carrier to use a satchel to gather and deliver all the mail to the houses on a city block without returning to the truck each time. * Over-Processing: Over-processing waste occurs when more effort or energy is input into a product or service than is strictly needed to add value to it. For the mail carrier over-processing occurs if they deliver a tracked package. The package may require a customer signature confirming deliver, as well as an electronic notification sent by the mail carrier, along with an electronic receipt. These are redundant, any one delivery confirmation method would accomplish the same goal. All three are not strictly necessary to confirm delivery.   The identification of waste, and striving to achieve the smallest amount of waste possible is applied to facility design scenarios as well. Usually, engineers will focus on a few of the 7 wastes to try to optimize the design such as motion, inventory, and transportation. For example the layout of a department store. Every store has similarities and differences depending on their customer base. If a department store is chosen as a system to study, the layout can be broken down into parts to identify the waste involved and try to reduce it with regards to any of the 7 wastes. In a store, a major form of waste is excessive motion (or travel). The layout of each section of the store could dictate how much travel must be done by a customer. Imagine for a moment that a store that has groceries places one aisle of breakfast foods on one side of the store but puts the dairy on the other side. This would cause a customer to have to travel from store end to store end in order to get milk for their cereal. It becomes important where items are placed and in what order so that a customer can find all their items efficiently without spending excess time walking. The relationship between products in the store play a large role in their placement. Similar products such as clothing and groceries are grouped together which is importance for customers to understand the layout of the store. These groupings help to place similar style items near other items that a customer may be searching for. This allows a customer to find all the items they were looking for by category easily and efficiently. In manufacturing, this is represented by sequential steps in the process being adjacent in the layout. If Process A is far away from Process B, then excess motion and time is wasted. Considering how different steps in the process (or departments) interact is important when designing a facility.  Another important factor in the layout of the store is the aisle-way size. By having a big enough aisle-way, more customers can simultaneously travel and pick out items at the same time. This helps to reduce the amount of waiting the each customer has. Similarly, the amount of check-stands also contributes to the amount of waiting that is done. Each of these wastes is considered by industrial engineers when they develop facility and system layouts.  Facility layout is a design based concept. It directly relates to the Next Generation Science Standards for middle school students in that it requires defining an engineering problem, developing multiple possible solutions since there is no one correct answer, and optimizing a design solution. Once the wastes have been considered for a system, an engineer takes this information into consideration along with design factors to create multiple iterations of layouts to be able to choose the most appropriate layout for their facility. Design factors that affect the facility layout include the building size, the size of each department or section, and the relationships between departments. Often times multiple layouts exist that meet the need of the system. Usually each has its own strengths and weaknesses when compared to one another. This is what makes facility layout a design concept, there is no clear-cut, single solution. The engineer must make the decision based on their objective and goals. Usually, upper-level management decides what the objectives and goals are for the facility, and the engineer must work to meet these goals. |

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| **Engage** |
| If you were tasked with designing the layout of a zoo, what must you consider? The pens for each of the animals must be designed, how would you choose where to place them? If there was a certain amount of space provided, how would you make sure all the animal pens fit? If you are trying to reduce waste (motion and transportation) how would you design the zoo? How does including a walkway for the guests affect the zoo design? |

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| **Explore** |
| **Experiment Questions**:  How can we reduce waste when designing a layout of a zoo?  How does having obstacles (the pond) effect the layout design?  How many “right” answers are there when designing a layout?  **Activity Preparation:**  1. For each LEGO kit to be used, prior to the start of the activity separate out groups of each color of LEGOs, and place the groups into ziplocs. This will help to allow more time for the activity. Below is a list of pieces that are not used in this activity. These pieces can be left in the box or set aside.  UnusedLEGOS.jpg *Figure 2: Unused LEGOs for facility design activity*  2.) Print the provided pdf file titled “LEGO Zoo Grid” Each team needs one grid to complete the activity. IMPORTANT - Provided PDF file makes use of 11x17 paper, the grid needs to be printed on this size in order for the activity to perform properly.  3.) Print the file “LEGO Zoo Rules and Guidelines” Each team will need one copy of this document.  4.) Give the provided presentation titled “SMILE Facility Design Student Lesson” in order to build student knowledge prior to the start of the activity.  **Procedure:**  **Before First Run**  1. Get in to groups of 4 or 5 students.  2. Hand out materials listed above to each group.    **Guidelines for designing the layout of the zoo:**  Goal:  Instructions:  You and your team are tasked with designing a zoo. The Lego kits that you have represent the animals of the zoo. Each color represents a different animal. The list of color and animals are provided below:  Dark Grey- Gorillas  Light Grey- Elephants  Blue- Dolphins  White- Polar Bears  Black- Zebras  Yellow- Lions    Guidelines for designing the layout of the zoo:  1) Each animal must be included in the design.  a. Draw the fencing around the animals with a pencil  b. Fences between two animals cannot be touching  2) There must be enough space between all animals and monuments for visitors to navigate the park. A two x two Lego piece must be able to fit between all walkways.  Example:    3) The visitors should be able to see all the animals before they leave the zoo. This means the  walkway must share a border with at least one side of each animal area.  4) None of the areas for the animals may touch the monuments on the Zoo grid (pond, visitor center, etc.)  5) The goal of designing the layout is to have the shortest path for the visitors to enter the zoo,  see all the animals, and exit the zoo.  6) Every square on the grid paper counts as 1 unit.  7) Visitors can only move up, down, left and right between square units (cannot move diagonally).  8) The owners of the zoo want the “Flow” of the zoo to be focused on “cool factor”.  a. The dolphins must be the first attraction by the entrance  b. The gorillas must be the last attraction before the exit  c. Focus on the arrangement of animals, which animals can be next to each other? Which  can’t.  3. For the activity, each team is to design the layout of the zoo. The time allowed to design the zoo will be 15-20 minutes. The groups will work to follow the provided guidelines and design the zoo.  4. After 15-20 minutes, have the groups count how many squares the visitors must travel to complete the zoo tour.  5. After the run, begin a discussion with the students about their group’s design.  Talking points:  Why did you place the animals in that order?  Was it hard to work around the pond and visitor information center?  Could the guests easily see all animals?  Did you have trouble fitting all the animals into the space provided?  6. Optional: Allow the students to share their groups design with the class and discuss why they designed the zoo the way they did  Connecting back to Manufacturing:  Just like designing the layout of the zoo, engineers have to fit all the machines and people working to manufacture products into certain spaces. Sometimes, certain obstacles like poles get in the way. Other times, certain machines have to be located in a certain place for safety or size reasons. Having limitations on where to put certain machines, or workstations, or departments makes it more difficult to reduce the amount of travel waste.  a) How would having more obstacles or guidelines effect designing a layout?  b) How could designing a zoo relate to manufacturing facilities? Especially considering that manufacturing has certain processes in a specific order, certain machines or workstations have to be located in a certain place, etc. |

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| **Explain** |
| 1.) How did your group’s design reduce waste?  2.) What is the most efficient type of path?  3.) Did your group draw the path first, or begin drawing the cages around the animals? How did this effect your design?  4.) What might be some obstacles that Industrial and Manufacturing engineers face when designing a facility?  5.) How does reducing the travel time save money?  6.) What makes reducing waste difficult?  7.) If more animals were added to the zoo, but no more space was given, how would you go about designing the zoo layout? |

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| **Elaborate** |
| 1.) How many different solutions were there?  2.) Why would wider walkways be better in a zoo? Why would narrower walkways be desired?  3.) What are some similar examples of everyday experiences that could use the principles of facility design and reduction of waste?  Potential Answers: Loading a dishwasher to fit all dishes.  Arranging furniture or desks in a classroom. |

**Resources**

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| **Additional Resources:**  **Resources Used:**  An “OSU Industrial Engineering Student Solutions” presentation aid is provided.  A presentation aid for this Facility Design lesson is provided.  The 11” X 17” Lego Zoo Grid is provided in PDF form.  A student sheet is provided that includes the rules and guidelines for this activity. |