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| **Unit 4 Modeling Skills**  |

**Preface**

Effectively applying a design process often involves a wide variety of modeling activities. During the initial phases of the design process, defining the problem and generating concepts brainstorming is often accompanied by concept modeling. Lists and mind maps are often used to document design ideas and concepts. As research is performed, graphical modeling and/or mathematical modeling can be used to represent gathered information. Graphical modeling can involve representing information in the form of charts, graphs, maps, or geometric figures. Mathematical modeling involves representing a phenomenon or behavior with an equation or a geometric representation. For instance, an environmental engineer who is developing a solution to handle and dispose of solid waste in an area for the next 20 years may wish to represent the volume of solid waste produced over the previous 20 years with a mathematical equation. The equation will allow the engineer to predict the waste production in the future.

Design ideas and alternatives are often modeled graphically. If the design solution involves a physical object, designers typically use sketching and drawing to represent design ideas. If the problem solution involves the design of systems or processes, charts, graphs, and maps may be employed to represent the proposed designs. Early in the design process, ideas are often sketched on paper for future refinement. As ideas are formalized, greater accuracy is required. This refinement may involve converting sketches to computer models and formal technical drawings.

Today, computers and software applications are tools often used in the solution of engineering problems. Computer modeling is frequently used to represent, analyze, document, and assess a design idea. Three-dimensional computer modeling of products allows designers to virtually create, manipulate, and test products and system prior to building and testing a physical model. A physical model is often desirable because it allows hands-on manipulation and testing of a product or system in its intended operating environment. However, computer modeling is especially helpful when building a physical model is difficult or expensive. For instance, in the case of large commercial and industrial buildings, which must be designed to carry a variety of load conditions, computer modeling provides an inexpensive means through which to model and test the load carrying capacity of the building structure. Or, if a chemical process is part of the design solution, a computer program can simulate the proposed process and efficiently allow adjustment of design factors (such as concentrations, temperature, and pressure) to hone in on a precise solution before large-scale physical testing is performed.

If the design process is applied to the design of a consumer product, it is almost always necessary to build a physical model for a variety of reasons. A physical model provides a representation of the design to which people can relate. They can see the design intent.  And, when the physical model is built to the design specifications, the product can be used for the intended purpose and tested. In addition, physical models help potential consumers and investors understand the product and can improve the chances of gaining financial support and customers.

The testing phase of the design process can also involve a variety of modeling techniques. Before testing can be performed, the test(s) itself must be designed, which can require the use of concept, graphical, mathematical, computer and/or physical models. Physical models of the design are often used to allow testing of the actual product. Computer modeling is used to represent the product and test a design when physical testing is not feasible or is prohibitively expensive. The data gathered during the testing phase of the design process is often represented with graphical and/or mathematical modeling.

In this lesson students will learn how to create a product from conception to reality and will employ a variety of modeling techniques. They will do this by applying the design process steps first-hand in the creation of their product. Students will live the life of a product designer and create a solution to a problem that exists for a company.

**Unit 4 – Concepts & Objectives**

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| **Concepts** | **Objectives** |
| An engineering design process involves a characteristic set of practices and steps. |          Identify and define the terminologyused in engineering design and development.         Identify the steps in an engineering design process and summarize the activities involved in each step of the process.         Complete a design project utilizing all steps of a design process, and find a solution that meets specific design requirements. |
| Brainstorming may take many forms and is used to generate a large number of innovative, creative ideas in a short time. |          Describe a variety of brainstorming techniques and rules for brainstorming.         Generate and document multiple ideas or solution paths to a problem through brainstorming. |
| A solution path is selected and justified by evaluating and comparing competing design solutions based on jointly developed and agreed-upon design criteria and constraints. |          Clearly justify and validate a selected solution path. |
| Physical models are created to represent and evaluate possible solutions using prototyping technique(s) chosen based on the presentation and/or testing requirements of a potential solution. |          Construct a testable prototype of a problem solution. |
| Problem solutions are optimized through evaluation and reflection and should be clearly communicated. |          Describe the design process used in the solution of a particular problem andreflect on all steps of the design process.          Justify and validate a problem solution.         Identify limitations in the design process and the problem solution and recommend possible improvements or caveats. |
| The scientific method guides the testing and evaluation of prototypes of a problem solution. |          Analyze the performance of a design during testing and judge the solution as viable or non-viable with respect to meeting the design requirements. |
| Statistical analysis of uni-variate data facilitates understanding and interpretation of numerical data and can be used to inform, justify, and validate a design or process. |          Calculate statistics related to central tendency including mean, median, and mode.         Use statistics to quantify information, support design decisions, and justify problem solutions.         Calculate statistics related to variation of data including standard deviation, interquartile range, and range. |
| Spreadsheet programs can be used to store, manipulate, represent, and analyze data. |          Use a spreadsheet program to store and manipulate raw data.         Use a spreadsheet program to graph bi-variate data and determine an appropriate mathematical model using regression analysis.         Use function tools within a spreadsheet program to calculate statistics for a set of data including mean, median, mode, quartiles, range, **interquatile range,** and standard deviation. |
| An equation is a statement of equality between two quantities that can be use to describe real phenomenon and solve problems. |          Represent constraints with equations or inequalities.         Formulate equations and inequalities to represent linear**, quadratic, simple rational, and exponential** relationships between quantities.         Compute (using technology) and interpret the correlation coefficient of a linear fit.         Construct a scatter plot to display bi-variate data, investigate patterns of association, and represent the association with a mathematical model (linear equation) when appropriate. |
| Solving mathematical equations and inequalities involves a logical process of reasoning and can be accomplished using a variety of strategies and technological tools. |          Solve equations for unknown quantities by determining appropriate substitutions for variables and manipulating the equations. |
| Functions describe a special relationship between two sets of data and can be used to represent real world relationships and to solve problems. |          Explain the term “function” and identify the set of inputs for the function as the domain and the set of outputs from the function as the range.         Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.         Build a function that describes a relationship between two quantities given a graph, a description of a relationship, or two input-output pairs.         Interpret a function to solve problems in the context of the data.         Interpret the slope (rate of change) and the intercept (constant term) of a linear function in the context of data. |
| Technical drawings convey information according to an established set of drawing practices which allow for detailed and universal interpretation of the drawing. |          Identify line types (including construction lines, object lines, hidden lines, cutting plane lines, section lines, and center lines) used on a technical drawing per ANSI Line Conventions and Lettering Y14.2M-2008 and explain the purpose of each line.         Determine the minimum number and types of views necessary to fully detail a part.         Choose and justify the choice for the best orthographic projection of an object to use as a front view on technical drawings.         Identify and correct errors and omissions in technical drawings including the line work, view selection, view orientation, appropriate scale, and annotations.         Create a set of working drawings to detail a design project.         Fabricate a simple object from technical drawings that may include an isometric view, orthographic projections, and a section view. |
| Dimensions, specific notes (such as hole and thread notes), and general notes (such as general tolerances) are included on technical drawings according to accepted practice and an established set of standards so as to convey size and location information about detailed parts, their features, and their configuration in assemblies. |          Dimension orthographic projections and section views of simple objects or parts according to a set of dimensioning standards and accepted practices.         Identify and correct errors and omissions in the dimensions applied in a technical drawing based on accepted practice and a set of dimensioning rules. |
| Hand sketching of multiple representations to fully and accurately detail simple objects or parts of objects is a technique used to convey visual and technical information about an object. |          Hand sketch isometric views of a simple object or part at a given scale using the actual object, a detailed verbal description of the object, a pictorial view of the object, or a set of orthographic projections.         Hand sketch orthographic projections at a given scale and in the correct orientation to fully detail an object or part using the actual object, a detailed verbal description of the object, or a pictorial an isometric view of the object. |
| Computer aided drafting and design (CAD) software packages facilitate virtual modeling of parts and assemblies and the creation of technical drawings. They are used to efficiently and accurately detail parts and assemblies according to standard engineering practice. |          Create three-dimensional solid models of parts within CAD from sketches or dimensioned drawings using appropriate geometric and dimensional constraints.         Generate CAD multi-view technical drawings, including orthographic projections, sections view(s), detail view(s), auxiliary view(s) and pictorial views, as necessary, showing appropriate scale, appropriate view selection, and correct view orientation to fully describe a part according to standard engineering practice.         Dimension and annotate (including specific and general notes) working drawings according to accepted engineering practice. Include dimensioning according to a set of dimensioning rules, proper hole and thread notes, proper tolerance annotation, and the inclusion of other notes necessary to fully describe a part according to standard engineering practice.         Explain each assembly constraint (including mate, flush, insert, and tangent), its role in an assembly model, and the degrees of freedom that it removes from the movement between parts.         Create assemblies of parts in CAD and use appropriate assembly constraints to create an assembly that allows correct realistic movement among parts. Manipulate the assembly model to demonstrate the movement. |
| Technical professionals clearly and accurately document and report their work using technical writing practice in multiple forms. |          Organize and express thoughts and information in a clear and concise manner.         Adjust voice and writing style to align with audience and purpose.         Support design ideas using a variety of convincing evidence.         Utilize project portfolios to present and justify design projects. |
| Sketches, drawings, and images are used to record and convey specific types of information depending upon the audience and the purpose of the communication. |          Create drawings or diagrams as representations of objects, ideas, events, or systems. |

**Essential Questions (Unit-Specific)**

1.    What is the role of models in the design process?

2.    How can we use technology to make the design and manufacture of a product more efficient and less prone to error?

3.    What is the purpose of a portfolio? How do you decide what information to include in a portfolio?

**Essential Questions (Course-Wide)**

1.    How does the design process promote the development of good solutions to technical problems?

2.    How can an engineer or technical professional effectively communicate ideas and solutions in a global community?

3.    How do inventors and innovators impact and shape society?

**Day-by-Day Plans**

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| **Day 1** | * **Essential Question: What is dimensional analysis and how can it help solve problems involving quantities?**
* The teacher will present **Introduction to Dimensioning.ppt** and distribute the **Dimensioning Guidelines** handout.
* Students will take notes and will refer to the Dimensioning Guidelines handout while the teacher presents Introduction to Dimensioning.ppt.
* The teacher will distribute **Activity 3.3 Linear Dimensions**.
* Students will work on numbers 1 – 4 of Activity 3.3 Linear Dimensions.
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| **Day 2-3** | * The teacher will distribute and introduce **Project 4.1 Puzzle Design Challenge**.
* The teacher will distribute and introduce **Activity 4.1a Puzzle Part Combinations**.
* Students will begin work on Activity 4.2 Puzzle Part Combinations and complete the activity for homework.
* **Essential Question: How can an engineer or technical professional effectively communicate ideas and solutions in a global community**
* The teacher will assess student work using **Activity 4.1a Puzzle Part Combinations Examples**for guidance.
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| **Day 4** |           The teacher will present **Mathematical Modeling.ppt**.         Students will take notes and complete data analysis in Excel as the teacher presents the process.         The teacher will distribute and introduce **Activity 4.1c Mathematical Modeling (PREVIEW)****.**         Students will begin work on Activity 4.4 Mathematical Modeling and complete numbers 1 through 7 for homework. |
| **Day 5** | * **Essential Question:**  **How can we use technology to make the design and manufacture of a product more efficient and less prone to error?**
* The teacher will distribute and introduce either **Activity 4.1d Software Modeling Introduction (Autodesk Digital STEAM)**or **Activity 4.1e Software Modeling Introduction (Video)**.
* Students will complete Activity 4.5 Software Modeling Introduction.
* The teacher will distribute **Activity 4.1f Software Modeling Orientation Reference** after either activity 4.1d or 4.1e are complete.
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| **Day 6 - 8** | * **Essential Question:**  **What is the role of models in the design process?**
* The teacher will present **Additive and Subtractive Solid Modeling.ppt**.and **Assembly Constraints.ppt** to assist students to assemble the puzzle cube parts for the Project 4.1 Puzzle Design Challenge.
* Students will take notes.
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| **Day 9** | * **Essential Question:**  **What is the purpose of a portfolio? How do you decide what information to include in a portfolio?**
* The teacher will present **Portfolios.ppt**. and **Creating Drawings in CAD.ppt**
* Students will take notes.
* Students will work on and complete Project 4.1 Puzzle Design Challenge.
* The teacher will assess student work using Project 4.1 Puzzle Design Challenge Rubric.
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**Standards and PLTW Concept and Objective Overviews**

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| **Unit 4 National Science Education Standards**  |

**Unifying Concepts and Processes:**  As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

         **Systems, order, and organization**

         **Evidence, models, and explanation**

         **Form and function**

**Science and Technology Standard E:** As a result of activities in grades 9-12, all students should develop

         **Abilities of technological design**

         **Understandings about science and technology**

**Science in Personal and Social Perspectives Standard F:** As a result of activities in grades 9-12, all students should develop understanding of

         **Science and technology in local, national, and global challenges**

**History and Nature of Science Standard G:** As a result of activities in grades 9-12, all students should develop understanding of

         **Science as a human endeavor**

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| **Unit 4 Standards for English Language Arts**  |

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| **Standard 4** | Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes. |
| **Standard 5** | Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes. |
| **Standard 6** | Students apply knowledge of language structure, language conventions (e.g. spelling and punctuation), media techniques, figurative language, and genre to create, critique, and discuss print and non-print texts. |

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| **Unit X Standards for Technological Literacy**  |

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| **Standard 2:  Students will develop an understanding of the core concepts of technology.** |
| **BM AA:** | Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.  |
| **BM BB:** | Optimization is an on going process or methodology of designing or making a product and is dependent on criteria and constraints. |
| **BM DD:** | Quality control is a planned process to ensure that a product, service, or system meets established criteria.  |
| **Standard 6:  Students will develop an understanding of the role of society in the development and use of technology.**  |
| **BM J:** | A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies. |
| **Standard 8:  Students will develop an understanding of the attributes of design.**  |
| **BM H:** | The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.   |
| **BM I:** | Design problems are seldom presented in a clearly defined form.  |
| **BM J:** | The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.   |
| **BM K:** | Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other. |
| **Standard 9:  Students will develop an understanding of engineering design.**  |
| **BM I:** | Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.  |
| **BM J:** | Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. |
| **BM K:** | A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.  |
| **BM L:** | The process of engineering design takes into account a number of factors. |
| **Standard 10:  Students will develop an understanding of the role of** **troubleshooting, research and development, invention and innovation, and experimentation in problem solving.** |
| **BM I:** | Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.  |
| **BM L:** | Many technological problems require a multidisciplinary approach. |
| **Standard 11:  Students will develop abilities to apply the design process.**  |
| **BM M:** | Identify the design problem to solve and decide whether or not to address it. |
| **BM N:** | Identify criteria and constraints and determine how these will affect the design process.   |
| **BM O:** | Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.   |
| **BM P:** | Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.   |
| **BM Q:** | Develop and produce a product or system using a design process.    |
| **BM R:** | Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. |
| **Standard 12:  Students will develop the abilities to use and maintain technological products and systems.**  |
| **BM P:** | Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate. |
| **Standard 17:  Students will develop an understanding of and be able to select and use information and communication technologies.**  |
| **BM M:** | Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.  |
| **BM N:** | Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.  |
| **BM P:** | There are many ways to communicate information, such as graphic and electronic means. |
| **BM Q:** | Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli. |
| **Standard 18:  Students will develop an understanding of and be able to select and use transportation technologies.**  |
| **BM J:** | Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture.  |
| **BM K:** | Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another.   |
| **BM L:** | Transportation services and methods have led to a population that is regularly on the move.   |
| **BM M:** | The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques. |
| **Standard 19:  Students will develop an understanding of and be able to select and use manufacturing technologies.**  |
| **BM L:** | Servicing keeps products in good operating condition.  |
| **BM M:** | Materials have different qualities and may be classified as natural, synthetic, or mixed.   |
| **BM N:** | Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.   |
| **BM O:** | Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.  Optimization is an on going process or methodology of designing or making a product and is dependent on criteria and constraints. |
| **BM P:** | The interchangeability of parts increases the effectiveness of manufacturing processes.   |
| **BM Q:** | Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products.   |
| **BM R:** | Marketing involves establishing a product’s identity, conducting research on its potential, advertising it, distributing it, and selling it. |
| **Standard 20:  Students will develop an understanding of and be able to select and use construction technologies.**  |
| **BM J:** | Infrastructure is the underlying base or basic framework of a system.   |
| **BM K:** | Structures are constructed using a variety of processes and procedures.   |
| **BM L:** | The design of structures includes a number of requirements.   |
| **BM M:** | Structures require maintenance, alteration, or renovation periodically to improve them or to alter their intended use.   |
| **BM N:** | Structures can include prefabricated materials. |