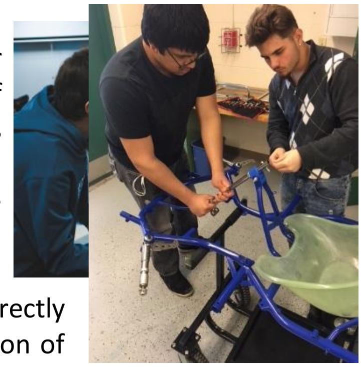
Module 2 Overview

Introduction to Engineering Design Process



The Hardware Store Science program's curriculum is appropriate for an introductory high school Integrated Chemistry and Physics (ICP) course or introduction to Career Technology Education (CTE) courses. The merging of the inquiry based Science experiments and the engineering design process leads to an integrated STEM course that prepares students for careers in STEM related professions. Throughout the program, students will engage with content from science, technology, engineering and math through the context of engaging problems solving activities and competitions. In the process, students learn technology, engineering and math concepts directly related to the theme of conservation of energy, as it applies to the motion of objects, chemical interactions, and electricity.

The hands-on projects, basic making skills and activities, and integration of all components of STEM (Science, Technology, Engineering, Math) provide an authentic means of encouraging student engagement. In addition, the one-year Hardware Store Science program addresses all state and national academic standards associated with an Integrated Chemistry Physics (ICP) course.

The engineering process, combined with fundamental technology, will be used during the learning of science principles and content. Understanding this way of organizing the developmental steps used to create, prototype, and manufacture items will greatly enhance student learning and retention of concepts that are otherwise abstract in nature. Applying scientific knowledge to solve everyday problems is one of the fundamental aspects of an engineering career, while seeing scientific phenomena in action will solidify the learning process.

Prototyping, building, testing, and producing usable products is a major job description of engineers and technicians today. The Engineering Design lessons provide students with first hand experience with not only the career tasks of an engineer, but the use of such tools as modeling software, 3D printing, and rapid prototyping. Each lesson will focus on one particular aspect of the engineer career field, culminating in the development of a usable model for conducting scientific investigations throughout the remainder of the Go-Kart Science Technology & Entrepreneur program. This thinking process will continue to be developed as students encounter more complex questions and scenarios.

While students will focus on the Engineering component of STEM, the science, technology, and math components will play a big part in successfully completing each task. Use of technology will be fundamental to the learning process and a working definition of technology will be vital to communicating student learning, as well as developing an understanding of career opportunities within STEM fields. Students will work with traditional hand tools, measurement and data collection devices, and modeling software and hardware (3D printing).Science concepts will guide the design process, and computational analysis will ensure that transitions from idea to final product/model are consistent.

The Program Introduction Module has the following components.

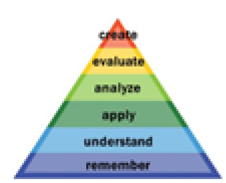
1. Objective and Lesson Plan. Statement of educational purpose of the module, learning objectives and sample lesson plan for the topic.
2. Investigations and karting Activities. Investigations include a description of (i) the experimental apparatus, (ii) the various steps needed for construction, (ii) detail instruction on one experiment, and (iv) inquiry questions. Karting activities include materials that have students using the go kart to learn related content within the context of motorsports and go-kart racing.
3. Background and Context. Material that describes the working knowledge behind phenomena that is being studied as well has how that phenomena connects to practical applications.
4. Practice Problems. End of lesson practice problems and that can be completed as Homework or an in-class activity. Each question is a review of a question found within the background materials and linked to specific questions found in the end of lesson quizzes.
5. Additional Lesson Resources (only available to the teacher). Includes (i) standard lesson components such as graphic organizers, bell assignments, slideshows etc., (ii) Practice Problems, (iii) answer keys with worked problems and (iv) links to helpful online resources.
6. Assessment Tools (only available to the teacher). Includes such things as (i) exit tickets, (ii) quizzes, (iii) unit assessments, and (iv) answer keys. . Each of these questions are linked to the background materials and practice problems.

Learning Objectives

During this Module students will be introduced to tolerances and dimensioning from the perspective of an engineer. Students will learn the use of calipers in obtaining dimensions of small objects, requiring precise measurements. Students will begin to create design ideas and component information relating to the Micro-Kart Challenge. The measurements and tolerances of associated component pieces will help ensure accuracy in later 3D printing. Students will apply the Engineering Design Process by participating in an engineering design challenge to create a model for studying translational motion and its causes. Students will first sketch their preliminary ideas prior to creating 3D models using CAD software and then 3D printing their experimental model chassis. Students will familiarize themselves with Tinkercad software, creating a chess piece of their own design. Once students are familiar with the tinkercad software they will design and print their MSTEM Accel Car chassis. Finally, students will use a design checklist to evaluate the final functional requirements of a rapid prototype chassis, including proposed improvements to sketch accuracy and prototyping effectiveness in meeting design requirements.

Guiding Questions

1. How are functionality and ease of assembly ensured by accuracy of dimensions and tolerances?



Learning Objectives (SWBAT)

- Define the importance of engineering tolerances and dimensions in the engineering design process using specific examples
- Use measuring tools to add 1:1 scale engineering tolerances and dimensions to describe MSTEM Accel Car adon components
- Repeat the 5 phases of the engineering design process as they are applied to the development of the MSTEM Accel Car Chassis

- Identify aspects of the 5 phases of the engineering design process that contribute to the rapid prototype design model
- Provide constructive feedback during a critique rapidly prototyped models based on the 5 phases of the engineering design process.

Key Concepts

- Measurements and dimensions
- Tolerance within product dimensions
- Caliper Use
- Rapid Prototyping
- Engineering Design Process

Unit Timeframe and Lesson Components

Traditional Classroom – 5 Days (45-55 minutes); *Day 4 Lesson Plan is dedicated to allowing student groups to rapid prototype a model "car". Days 5 students utilize checklists for evaluating prototypes and models.*

Lesson – Engineering Design Process Introduction	Connected Resources	STEM Content
Engage – Students will learn the use of calipers for making accurate measurements of small objects, by measuring specific dimensions associated with the size of Gummi Bear candy. Students will then compare the dimensions from a total of 10 gummi bear candies to develop an appreciation for creating objects within a small dimensional tolerance. This will be reinforced throughout the curricular program, helping students gain an intuitive feel for the need to ensure accuracy in measurements. Students will apply the lesson learned to both the design process and experimental data collection. *(ESPS.2, 5, PS.6, IED-6.10, STEM-T.2, 5)* ***Explore –*** Students will use their knowledge of variation within a sample to understand that engineering tolerances are accounted for in design and manufacturing. Students will then take a deeper look at variation within a sample as they learn about tolerances; in measurements, dimensions, and design development. Students then apply principles of tolerance to parts that fit together. Finally, students apply their learning to the development of acceptable tolerances to be utilized during the upcoming MSTEM Accel Car design project. *(ESPS.2, 5, PS.6, IED-1.5, 6.10, STEM-T.2, 5)* ***Explain:*** Students will relate the 5 phases of the engineering design process to a design challenge. Students will begin by learning the value of question storming and how it contrasts to brainstorming. Then students will participate in a brainstorming activity with the aid of the SCAMPER acronym guiding their thinking. Students will apply this understanding to the development of a first iteration chassis design for the	*STEM Content Document,* ***2.0*** *Extended Lesson Plan,* ***2.1*** *Lesson Log* *ABC Vocabulary Reading Strategy* *Venn Diagram Graphic Organizer* *Gummi BEar Tolerances & Dimensions,* ***2.3a*** *Engineering Tolerances Slideshow,* ***2.3b*** *MSTEM Accel Car Component Dimensions,* ***2.3c*** *Engineering Design Process Slideshow,* ***2.3d*** *SCAMPER Reference Sheet,* ***2.5a*** *MSTEM Accel Car Design Checklist,* ***2.5b*** ***Additional Resources***	*Collaboration* *Dimensions and Dimensioning* *Engineering Design Process* *Measurement* *Problem Solving* *Tolerances*

MSTEM Accel Car project. Finally students will learn the value of rapid prototyping prior to being provided an opportunity to construct their own prototype of an accel car chassis. Students will summarize their learning throughout the learning process. *(ESPS.3, IED-1.5, 6.10, STEM-T.2, 5)* ***Engineer:*** Design teams will develop an accel car prototype chassis using a tape measure, miter saw, plywood, screw spacers/straw, and a EUDAX 82pcs Gear Set with Wheels and Axles. Students will apply the measurements and tolerances from their *MSTEM Accel Car Component Dimensions Student Activity Sheet* to guide their prototype construction. Students will then evaluate their prototype based on the 5 phases of the engineering design process and their use of the acronym SCAMPER. The model built will be utilized during the evaluate lesson of this learning module *(ESPS.3, PS.7, 8, IED-1.5, 6.10, STEM-T.2, 5)* ***Evaluate –*** Student groups will utilize the *MSTEM Accel Car Design Checklist Student Activity Sheet to conduct a personal evaluation of their rapidly prototyped accel car chassis, prior to conducting a peer evaluation. Students will judge models based on requirements for the final MSTEM Accel Car 3D printed chassis, in an effort to inspire further design modifications and improvements. Finally, design teams will share their critiques of other models and provide positive, constructive feedback to other design teams. (ESPS.3, POE-5.3, STEM-T.2, 5)* ***Deliverables*** ● Gummi Bear Tolerances & Dimensions ● MSTEM Accel Car Component Dimensions ● Rapid Prototype Models ● MSTEM Accel Car Design Checklist	*MSTEM Accel Car Body - STL File* *MSTEM Accel Car Topper - STL File*	

Materials and Equipment Needed

- Blackboard or Overhead Projector
- Computers with Internet access
- Calipers (for student pairs or groups of up to 3)
- Albanese Gummi Bears
- 1/4 plywood (2-1/4 inches wide) (1/4” x 2 x 2 ACX Handi-Panel, $5.19 @ Menards)
- 4 – (1/4 x 3/4) #6 Screw Spacer (Midwest Fastener® #6 x ¼” x ¾” Aluminum Spacer for $0.79 @ Menards)
- EUDAX 82 pcs Plastic Gear Set with Wheels and Axles ($8.99 @ https://www.amazon.com/EUDAX-Plastic-Assortment-accessories-Bushings/dp/B0776ZPP7V?ref_=ast_sto_dp) *This set will be used for future investigations into gears, and during the Chemistry and Electricity Modules*

- Hand Saw with Miter Box base (MasterForce® 14” Hand Back Saw with Miter Box, $7.98 @ Menards)
- Tape measure (Performax 12 foot, $4.99 @ Menards)

Optional Materials
- 3-D Printed M-STEM Accel Car Body (STL file found at hardwarestorescience.org This file will open using Ultimaker Cura software, a free software download. The File can also be found at Tinkercad.com by searching M-STEM Accel Car Body)
- 3-D Printed M-STEM Wheels (STL file found at hardwarestorescience.org This file will open using Ultimaker Cura software, a free software download. The File can also be found at Tinkercad.com by searching M-STEM Wheels)
- Wire Clothes hanger (10 pack, $1.44 @ Walmart)
- #20 O-Ring (1-3/16” O.D. x 1” I.D., $0.79 @ Menards) (Qty – 4)

Assessment
- ***Engineering Design Process,*** to assess student learning and understanding of tolerance, dimensions, and the 5 phases of the engineering design process.

Career Connections

Throughout this unit students will learn critical skills related to human-centered approaches to engineering design and competencies in a repeating design process; design, prototype, test, redesign. These skills will benefit students within all STEM career fields, especially technology and engineering. Broader career pathways include occupational pathways such as; manufacturing, Electrical Engineering, Mechanical Engineering, user experience (UX) design, and computer science.

Students will be introduced to the use of common hand tools and measuring devices as they relate to fabrication and assembly of products and components. These skills will benefit students within STEM career fields, especially construction, building trades, craftsman, and technicians. Broader career pathways include occupational pathways such as; commercial and residential contracting, machine shop technician/tradesman, and advanced manufacturing.

Students will become familiar with project management as it pertains to time management, managing resources and supplies, and developing project goals and outlines. These skills will benefit students within STEM career fields, especially science, technology, and engineering. Broader career pathways include management and administration activities in occupational pathways such as; Advanced Manufacturing, Engineering, user experience (UX) design, computer science, commercial and residential contracting, machine shop technician/tradesman, and advanced manufacturing.

Indiana based employers with career opportunities utilizing the skills taught in this lesson include: AES Corporation, Delta Faucet Company, Nidec Motor Corporation, Subaru of Indiana Automotive, Adidas, Kort Builders, J.R. Kell Company, Ely Lily and Company, and Wabash National Corporation.

Indiana Academic Standards

- Science and Engineering Process Standards:
  - SEPS.2 Developing and using models and tools
  - SEPS.3 Constructing and performing investigations
  - SEPS.5 Using mathematics and computational thinking
- Math Process Standards
  - PS.6 Attend to precision – Communicate precisely, use terms and symbols appropriately, specify units of measure, and calculate accurately and efficiently

- PS.7 Look for and make use of structure - Explain patterns and structures, know and explain properties that apply *(cumulative, for example)*
- PS.8 Look for and express regularity and repeated reasoning - Look for repetition in problems, explore and find short cuts, take repetitions and generalize into new situations using newfound shortcuts, check answers for reasonableness

- Introduction to Engineering Design Standards
  - IED-1.5 Students perform the steps of the design process to develop and analyse products and systems – Describe the steps in the design process, apply the steps of the design process as they are used to solve the problem, describe the iterative nature of the design loop, assess and refine original design solutions based upon reflection, critique, practice, and research.
  - IED-6.10 Students create designs using a variety of modeling techniques to communicate information – Formulate methods of communicating designs using various forms of modeling such as conceptual, graphical, mathematical, physical, or computer modeling.
- Principles of Engineering non-PLTW Standards
  - POE-5.3 Students apply the laws of motion as they apply to principles of engineering – Explain how gravity impacts motion.
- ***Technology Standards related to STEM Careers***
  - ***STEM-T.2*** Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.
  - ***STEM-T.5*** Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.

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