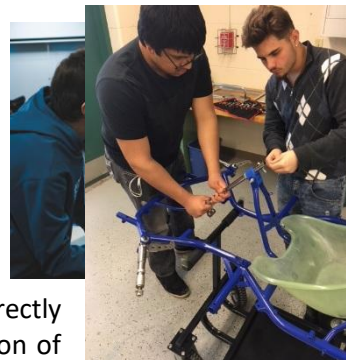


Module 3 Overview

Application of The 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 as 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 apply the engineering design process to create an educational model for investigating translational motion. They will then evaluate preliminary design ideas and submit a final design proposal for further development in 3D modeling software, and eventual 3D printing. Students will investigate orthographic projections as a means of communicating design concepts to design consultants, engineers, and technicians. Students will familiarize themselves with tinkercad.com (or CAD software of your choice) modeling tools during the process of creating a chess pawn. Finally, students will connect 3D printing to the modeling/prototyping stages of the engineering design process. Students are organized into design teams of 2 or 3 individuals (depending upon class size) and tasked with modeling and 3D printing an MSTEM Accel car chassis based off of their individual sketches and the design constraints inherent in the problem. Once 3D modeling is completed, design teams must submit their STL file for printing.

Guiding Questions

1. How are functionality and ease of assembly ensured by accuracy of dimensions and tolerances?
2. How do 3D modeling software and 3D printing provide an effective tool for engineers to develop working prototypes and models?



Learning Objectives (SWBAT)

- Repeat 3D modeling attributes and activities to design and model a unique variation to a previously modded 3D object.
- Describe the steps used for the creation of a simple 3D modeled object
- Apply the engineering design process to solve problems within established constraints and materials specifications.

- Utilize a final checklist of functional requirements for the assembled MSTEM Accel Car with a chassis that was modeled and 3D printed in the previous lesson.
- Execute the engineering design process from conception of idea to 3D printing of prototype model.

Key Concepts

- Measurements and dimensions
- Tolerance within product dimensions
- Caliper Use
- Rapid Prototyping
- Engineering Design Process
- Prototyping/Modeling
- 3D Printing

Unit Timeframe and Lesson Components

Traditional Classroom – 11 Days (45-55 minutes); Days 2 and 3 students use Tinkercad modeling software and begin printing their 3D models. Days 5 students utilize checklists for evaluating prototypes and models.

Lesson – Applications of the Design Process	Connected Resources	STEM Content
<p>Engage – Students will apply the engineering design process to create a preliminary solution to the design challenge of creating an educational model for investigating translational motion. Students will be given design constraints and asked to generate 3 to 4 sketches of different chassis consistent with the design constraints. Students will evaluate preliminary sketches in order to decide upon a final chassis design proposal to submit for further development in 3D modeling software, and eventual 3D printing of the modeled proposed chassis design. (SEPS.2, IED-1.5, 6.10, POE-5.3, STEM-T.2, 3)</p> <p>Explore – Students will investigate orthographic projections as a means of communicating design concepts to peers and colleagues. Students will complete a web activity to learn about orthographic projections - how to create them and their value in discriminating information to design consultants, engineers, and technicians. Students will model fundamental orthographic projection features such as line types, reference planes, and image manipulation. Students will utilize tinkercad.com (or CAD software of your choice) to create a chess pawn model, after completing a lesson to familiarize students to the basic modeling functions inherent within CAD software programs. (SEPS.2, IED-1.5, 6.10, POE-5.3, STEM-T.2, 3)</p> <p>Explain: Students will create a short presentation of their 3D modeled Chess Pawn and provide reasoning for the design elements they incorporated. Presentations will provide a sequence used during the modeling process of their chess pawn. Students will next engage in a discussion of 3D printing. Students will learn a quick, abbreviated history of 3D printing and then role</p>	<p><i>STEM Content Document, 3.0</i></p> <p><i>Extended Lesson Plan, 3.1</i></p> <p><i>Lesson Log</i></p> <p><i>Four Square Graphic Organizer</i></p> <p><i>#Hashtag Vocabulary Reading Strategy</i></p> <p><i>Modeling Translational Motion, 3.3a</i></p> <p><i>Orthographic Projection, 3.3b</i></p> <p><i>Tinkercad and 3D Modeling, 3.3c</i></p> <p><i>Prototyping Slideshow, 3.3d</i></p> <p><i>MSTEM Accel Car 3D Modeling, 3.3e</i></p> <p><i>SCAMPER Reference Sheet, 3.5a</i></p> <p><i>MSTEM Accel Car Design Checklist, 3.5b</i></p> <p><u>Additional Resources</u></p>	<p><i>Checklist Application</i></p> <p><i>Collaboration</i></p> <p><i>Dimensions and Dimensioning</i></p> <p><i>Engineering Design Process</i></p> <p><i>Measurement</i></p> <p><i>Modeling and Modeling Software</i></p> <p><i>3D Printing</i></p> <p><i>Problem Solving</i></p> <p><i>Tolerances</i></p>

<p>play through the use of 3D printing with the world of theatrical productions. Finally students will connect 3D printing to the modeling/prototyping stages of the engineering design process. (SEPS.2, IED-1.5, 6.10, POE-5.3, STEM-T.2, 3)</p> <p>Engineer: Students are organized into design teams of 2 or 3 individuals (depending upon class size) and tasked with modeling and 3D printing an MSTEM Accel car chassis based off of their individual sketches and the design constraints inherent in the problem. Design teams must present their proposed model for instructor approval prior to modeling within tinkercad.com (or CAD software of choice). Once 3D modeling is completed, design teams must submit their STL file to the instructor prior to 3D printing of chassis. Design teams are encouraged to utilize all phases of the engineering design process to ensure that models are ready for prosecution. (SEPS.2, IED-1.5, 6.10, POE-5.3, STEM-T.2, 3)</p> <p>Evaluate – Student design teams will present their completed, and assembled MSTEM Accel Car to classroom peers, and community experts if possible. Each model will be evaluated using the MSTEM Accel Car Design Checklist. Design teams will then display their assembled MSTEM Accel Car alongside their design process documentation, for a gallery walk activity and discussion. The discussion will focus on comparing models to expected constraints and design feature outcomes. Community partners experienced in modeling, prototyping, product development or other related career fields could be used as impartial judges and provide real-world feedback and commentary. (SEPS.2, IED-1.5, 6.10, POE-5.3, STEM-T.2, 3)</p> <p>Deliverables</p> <ul style="list-style-type: none"> ● Modeling Translational Motion Student Activity Sheet ● Orthographic Projection Student Activity Sheet ● Tinkercad and 3D Modeling Student Activity Sheet with Design Link ● MSTEM Accel Car 3D Modeling Student Activity Sheet ● Final MSEM Accel Car Models ● MSTEM Accel Car Design Checklist 	<p><i>MSTEM Accel Car Body - STL File</i></p> <p><i>MSTEM Accel Car Topper - STL File</i></p>	
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Materials and Equipment Needed

- Blackboard or Overhead Projector

- Computers with Internet access
- 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 1/4" x 3/4" 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 hardwarestore.science.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 hardwarestore.science.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

- **MSTEM Accel Car Model**, to assess student learning and understanding of the design process through the development, design, and 3D Printing of their MSTEM Accel Car that will be utilized during the Seed Velocity Acceleration Module. *Each group is scored by averaging peer evaluations using the MSTEM Accel Car Design Checklist.*

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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