TAMALPAIS UNION HIGH SCHOOL DISTRICT
LARKSPUR, CA

Course of Study
ENGINEERING DESIGN

GENERAL COURSE DESCRIPTION

Engineering Design teaches, and has students experience, design -- solutions to engineering challenges using: engineering drawing and sketching, an engineering design cycle, iterative design, precision measurement, applied mathematics, data acquisition and data analysis. Students will advance Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) skills and computer programming skills to an intermediate level (Principles of Technology provides introductory level instruction in these skills). Student will understand and analyze the performance of a system quantitatively, theorize about ways to improve the performance and then test their theories. Students document and discuss all project results in a web-based project portfolio. This portfolio is a continuation of the one created in Principles of Technology (for students who took that class) or the beginning of one for students new to the program.

The master rubric (shown below) contains all course objectives. Each unit does NOT work towards all course objectives, but rather each unit works to advance students towards proficiency in several course objectives. By the end of the course, after completing all units, students will be proficient in all course objectives. The units are described in general terms and one specific example project is described for each. Example projects provide clarity, support, and ideas for teachers offering this course and are in no way requirements, expectation or boundaries. There are many ways a creative teacher could meet the unit expectations, other than those provided in the example projects or the appendix.

Schools where the course will be taught: TUHSD Comprehensive sites

Length of course: one year

Subject area and discipline: Engineering, applied technology

Course Certification: UC approved as (g) elective

Pre-requisites and/or Co-requisites: Demonstrated proficiency in Principles of Technology, or instructor approval

Grade levels: 10th or 11th (exceptions at instructor's discretion)

Textbooks or other supporting material: none

COURSE CONTENT

Simple machines	Intermediate level CAD/CAM
Precision Measurement	Circuits, Electricity and Magnetism
Design using applied math	Intermediate level Computer Programming
Data Collection and analysis	Engineering Design Cycle and iterative design

Engineering Drawing and Sketching ("mechanical drafting")

C**OURSE** O**BJECTIVES** *upon successful completion of the course, students will be able to:*

Safely use and care for shop tools, machinery and equipment
Independently wire electrical circuits to accomplish a given task
Collect data, analyze data and write analytically about data results
Understand the purpose of, and implement the Engineering Design Cycle
Use sketching, measurement, and CAD skills as tools to develop a design idea
Write and execute intermediate level programming code to interact with multiple electronic inputs and out puts
Analyze a system to determine its efficiency/performance and understand what and how characteristics of the system impact efficiency/performance
Work in teams toward common goal
Evaluate personal level of interest in course content

METHODS OF EVALUATION

- Success of the actual project based on project goals
- Successful achievement of the course objectives (rubric below)

Engineering Design: Course Objectives and Proficiency Scale				
COURSE OBJECTIVES **(Upon completion of the course, student will be able to...)**	**1 (emerging)**	**2 (developing)**	**3 (Meets expectations)**	**4 (exceeds expectations)**
Collect data, analyze data and write analytically about data results	Understand how data strengthens arguments and understandings and how these understandings influence design decisions	With guidance, collect data from a given system. With guidance, analyze the results and use the results to explain or make a design decision	Independently collect data identified as important to understanding a system. Independently analyze the data and follow a provided template to write analytically about the results	Identify what data would be best to collect to further understand a system. Independently collect, analyze and write analytically about the data results
design and wire electrical circuits to accomplish a given task	See a wiring diagram and understand the circuit's purpose	Follow current through a wiring diagram and, with guidance, follow wiring documentation to build a circuit	Create a circuit based on a provided wiring diagram. Create a wiring diagram from a given circuit	Given an electronic task, independently design and wire a circuit to accomplish the task.
Use sketching, measurement and CAD skills as tools to develop design ideas	Understand the idea that further defining a design idea (through sketching or CAD) enables the design idea to develop	Create engineering drawings of a simple, example object using both hand sketching and CAD. Learn and apply measurement skills	Demonstrate development of a design idea for a part through the use of sketching and CAD. Sketch complex, multi-part assemblies of an existing device. Identify critical and non-critical design measurements.	Use sketching and CAD to develop a design idea involving a multi-part assembly. Properly communicate the measurement and tolerance information of the design idea.

Course Objectives (continued)	1 (emerging)	2 (developing)	3 (Meets expectations)	4 (exceeds expectations)
Write and execute intermediate level programing code to interact with multiple electronic inputs and outputs in order to accomplish a project goal	Understand the project goal. Program a controller to control an output based on the status of an input	Understand the details of a provided intermediate level programing code. With guidance, write code to have a controller make simple decisions based on the status of system inputs.	With guidance, implement third party inputs or outputs into a system. With guidance, use intermediate level programing code and structures (ex: nested statements) to accomplish a project goal.	Independently select third party equipment based on project goal. Utilize intermediate level programing code and structures to use the third party equipment in order to accomplish a project goal
Analyze a system to determine its efficiency and understand what and how characteristics of the system impact efficiency	Understand the concepts of power-in, power-out, losses of a system and how each relates to the system's efficiency	With guidance, be able to correctly analyze the efficiency of a provided, example system.	Independently and accurately analyze the efficiency of their project. Describe ways to improve efficiency	Use understandings of efficiency to drive project decisions. Theorize ways to improve efficiency and demonstrate associated efficiency improvements
Safely use and care for shop tools, machinery and equipment while developing craftsmanship skills	Student understands shop responsibilities. Student can identify tools and understands tool functions. Student understands the benefits of a having a plan.	Student cleans and takes care of the shop when prompted. Student can use tools safely for their intended purpose. Student can create a plan of what to fabricate, and can follow a given plan.	Student takes ownership of shop condition and tool usage. Student can independently select a tool for a given need. Student can successfully create a plan, fabricate something and have it come out like the plan ("craftsmanship")	Student self-identifies improvements to the way the shop operates. Student independently uses understandings of tool functionality to make project planning decisions. Fabrication results are exact to the plan.
Successfully work in teams toward a common goal	Student understands the common goal of the team	When prompted with specific tasks, student contributes towards the common goal of the team	Student can independently identify tasks that valuably contribute to the team's progress towards the common goal. The results from this student are valuable contributions.	Student can identify tasks necessary to achieve the team's common goal. Student and the team can work independently to delegate tasks, execute the tasks and achieve the common goal.
Evaluate personal level of interest in the course content	Student understands what content is to be covered in the course	Student experiences the course content and understands that the content is the beginning of possible further study	Student understands career and further study opportunities in the areas of the course content	Student understands lifestyle of individuals working in the industry related to the course content and understands the pathway to follow to obtain such a career

The above rubric is a static image of this live document and may be slightly behind current progression

Unit-by-Unit Description

Unit 1: Simple Machines, Engineering Drawing and Sketching

Students learn to sketch given objects following current engineering drawing methods. Students learn the basics of simple machines. Students then learn to sketch design ideas involving simple machines and develop their ideas following current engineering drawing methods. Students then fabricate their simple machine ideas and draw the fabricated pieces using engineering drawing methods. Students learn what tolerances are and the tolerance requirements for various types of part interactions (ex: press fit). Students learn types of geometric constraints (ex: tangent, flush, parallel, perpendicular). Students learn proper dimensioning rules for drawings, how to annotate drawings and the value of and how to create section views. Students post documentation and discussion of results in their engineering portfolios.

Example project: Hydraulic Robot

Students collaborate in trios to design and build one hydraulic robot to execute three simple-machine based functions: grab a tennis ball, lift the ball and the "grabber," turn the entire assembly 180 degrees, and then deposit the ball into a target cup. Sketches of the system are to be completed and approved prior to construction. Upon demonstration of the robot functionality, groups then work together to create an engineering drawing of the completed device. Note: this unit begins with students learning orthographic and isometric drawing/sketching techniques through guided activities involving drawing simple objects. Students also are introduced to simple machines through lecture and activities. "Hydraulics" in this sense are two 35ml catheter syringes connected on opposite ends of one 3' section of plastic tubing. When one syringe (water filled) is depressed, the opposite syringe (originally retracted) will extend, and vice versa. Final deliverables from this project are the functioning robot, as well as properly drawn and dimensioned drawings of the robot. All deliverables are to be documented and discussed in the students' engineering portfolio.

COURSE CONTENT

Work in teams toward common goals

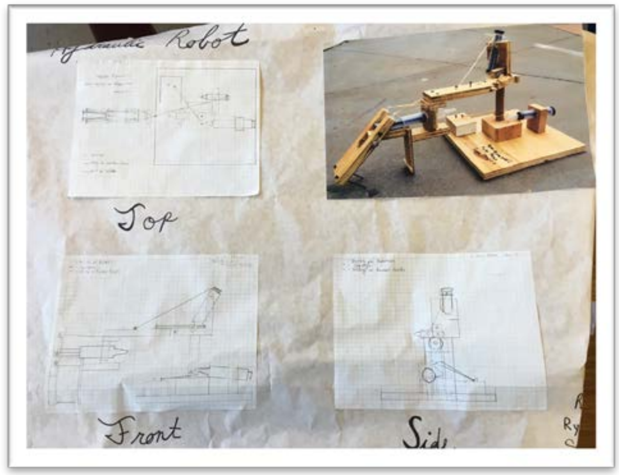
Evaluate personal level of interest in the course content

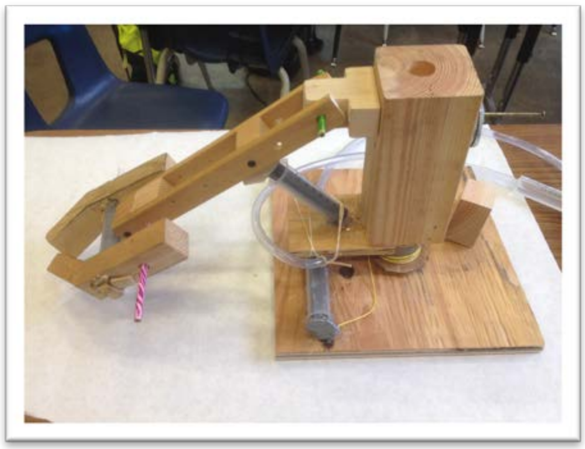
Use sketching and CAD skills as tools to develop a design idea

Safely use and care for shop tools, machinery and equipment while developing craftsmanship skills

Engineering Drawing and Sketching ("mechanical drafting")

Unit content and depth of progression towards course objectives for the Hydraulic Robot





Unit 2: Intermediate Computer Programming

Students advance programing skills from basic (being able to control blinking lights after detecting an input from a button), to intermediate (being able to control motion, sound and lights based on the input from various input sources such as sonar, light sensors.) Students learn intermediate level coding structures (ex: nested statements). The motivation for students to accomplish the learning described above should be some sort of challenge with clearly defined success criteria.

Example project: The Autonomous Robot

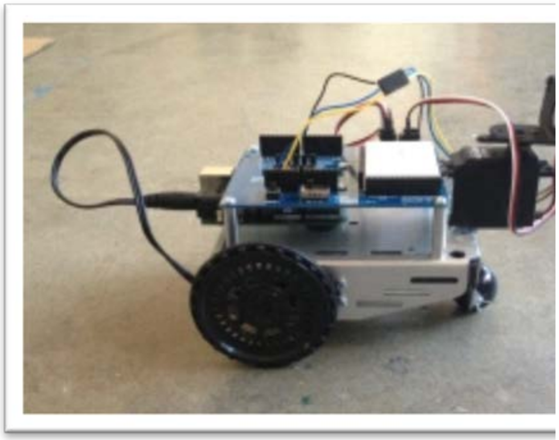
Students work independently to program a robot to advance from a starting square to an ending square by controlling outputs. Individual students then advance their programming of the robot to read optical inputs for the purpose of tracking a black line on a white background. Ultimately, students use ultrasonic sensors attached to a servo to “scan” for walls and to navigate autonomously through a maze as quickly as possible.

TARGET COURSE OBJECTIVES FOR THE AUTONOMOUS ROBOT

- Work in teams toward a common goal
- Design and wire electrical circuits to accomplish a given task

- Write and execute intermediate level programing code to interact with multiple electronic inputs and outputs in order to accomplish a project goal

Images *Tl to Br:* Example robot, First challenge (starting and ending box), Line challenge, Maze challenge



https://www.youtube.com/watch?v=ls-2r2T6RzY

Unit content and depth of progression towards course objectives for the Autonomous Robot

Unit 3: Circuits, Electricity and Magnetism

Students learn and apply the concepts of electromagnetism to create a device that does measureable work. The students learn to measure the amount of work done and then theorize ways to optimize the device to make it more efficient. Students modify their device to test their theory, measure the results and then write analytically about how the original and modified device compare. The deliverables of this unit are the functioning device and documentation/discussion of the results in the student's portfolio.

Example project: The DC motor

Students learn the concepts of electromagnetism through introductory activities such as making a compass needle move using batteries and wires, or building a mini-speaker out of household supplies.

Once students are introduced to the concept of electromagnetism, they are guided through the creation and design of a direct current motor. The motor axle is then equipped with a spool and students are tasked to optimize their motor to wind string connected to a hanging mass as quickly as possible. Students capture video of the mass moving as the motor winds and then are shown how to analyze the mass to calculate motor performance. Students speculate ways to improve the motor (ex: use carbon spring brushes, move the armature and stators closer together, etc.). Once they have decided on something to improve, students make the changes, independently record the results and then write analytically about how the modified motor performance compared to the original. Results are documented and discussed in the student's portfolio.

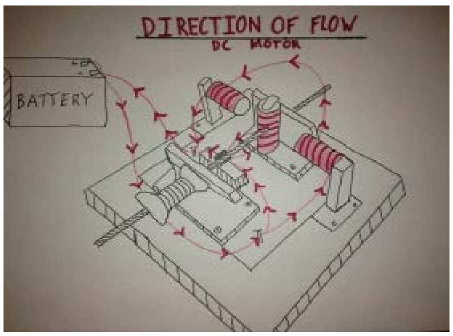
TARGET COURSE OBJECTIVES FOR THE DC MOTOR

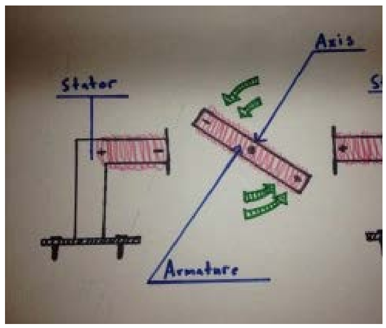
Collect data, analyze data and write analytically about data results

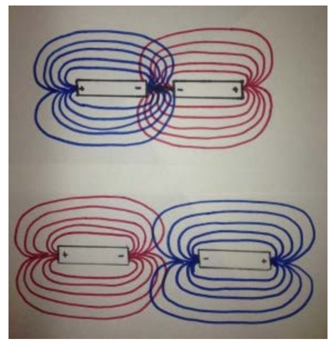
Independently wire electrical circuits to accomplish a given task

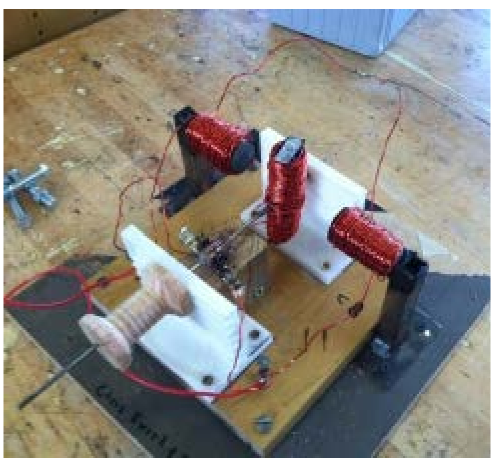
Analyze a system to determine its efficiency and understand what and how characteristics of the system impact efficiency

Images *l to r*: Student sketches of wiring, system and magnetic fields.

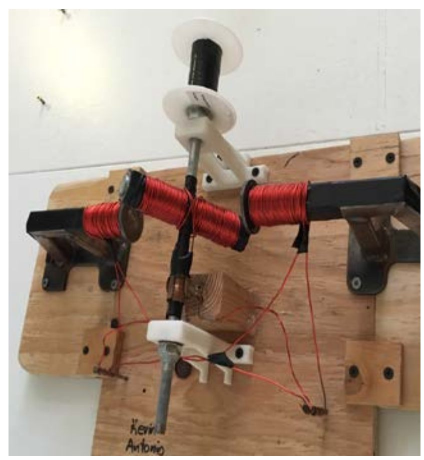








Images: Student motors



Unit content and depth of progression towards course objectives for the DC Motor

https://www.youtube.com/watch?v=2tXT10uLgD4
https://www.youtube.com/watch?v=j4QKzbpyKCI

Unit 4: Engineering Design Cycle

Students learn the engineering design cycle and understand it is a process and a tool engineers use to solve challenges in an organized, logical way. Students are given an opportunity to apply the cycle and to then reflect on their experience. Results of the project are documented and discussed in the student portfolio.

Example project: Cardboard Boats

Students work in groups of three to progress through the process of engineering design in order to create a solution to a fictitious challenge related to tsunami relief, to design and create the least expensive, smallest boat out of cardboard that can keep a person afloat in water. One example process of engineering design is as follows:

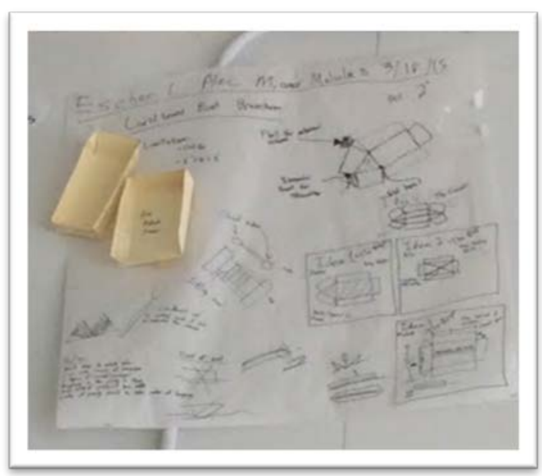
1. Define the problem
2. Identify criteria and constraints
3. Brainstorm
4. Research and generate ideas
5. Explore possibilities
6. Select an approach
7. Build a model or prototype
8. Test and evaluate
9. Refine the design
10. Make, create, build
11. Evaluate and communicate results.

In addition to the engineering design cycle, students are introduced to spreadsheets in order to make and update a bill of materials for their boat, documenting the amount and cost of each project resource. (ex: paraffin wax, hot glue, duct tape, flex seal, etc.)

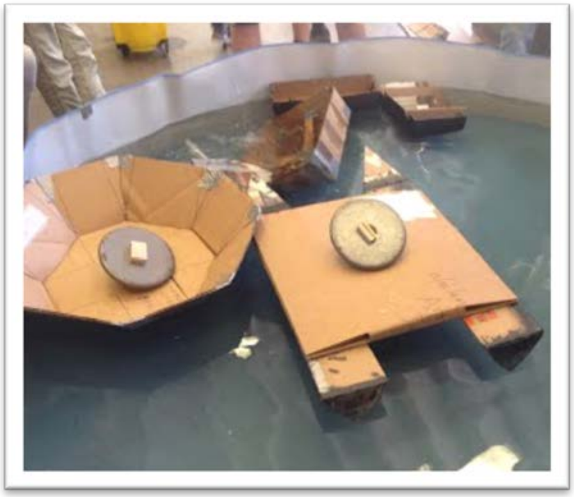
TARGET COURSE OBJECTIVES FOR THE CARDBOARD BOAT PROJECT

- Work in teams toward a common goal
- Understand the purpose of, and implement, the Engineering Design Cycle

Images: Engineering design cycle, brainstorm session notes



Images: Prototype testing in the mini-pool, full scale testing in the pool



Unit content and depth of progression towards course objectives for the Cardboard Boats

Unit 5: Applied Mathematics, Data Collection and Analysis

Students apply a mathematical concept to drive design decisions in order to build a device to perform a measureable task. Students measure and record the performance of the device and then analyze the connection between the original mathematical concept and the resulting device performance. Students write analytically about the result. The deliverables of this unit are the functioning device and documentation/discussion of the results in the student's portfolio.

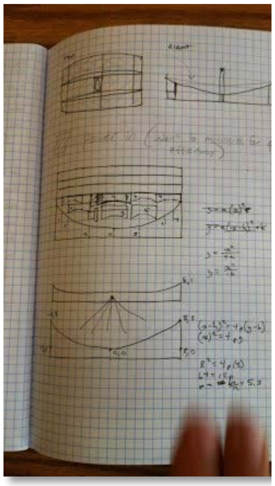
Example project: Solar Cooker

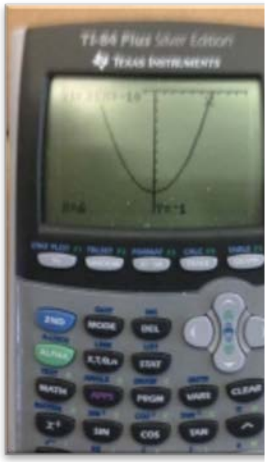
Students work with a partner to determine an ideal parabolic shape to best direct sunlight onto a target object to be cooked. Students then plot the parabolic shape on cardboard, cut out copies and then use them as structural ribs of a cooker that is then lined with reflective material such as aluminum foil. Students use some form of temperature data collection technology (ex: Vernier temperature probes) to document the temperature change over time for an object cooked in the cooker that has a known heat capacity (ex: hotdog). Temperature increase over time and heat capacity enable students to calculate the power entering the object being cooked, aka: the "power used." Students also calculate the power entering the cooker using the known sun power data (ex: 1300 watts/meter^2) and the area of the cooker's opening for light. These pieces of data enable students to calculate the "power in." Students then calculate the system's efficiency using the "power in" and the "power used." Students present their results to the class and observe other teams do the same. Students document and discuss their project results, their conceptual understanding of efficiency and trends they see among relatively high and low efficiency of their peer's cookers in their portfolio.

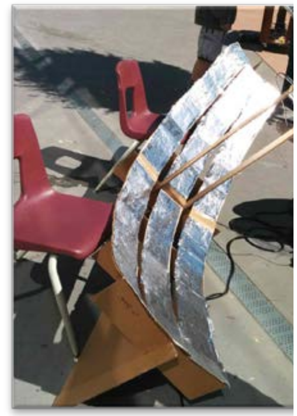
TARGET COURSE OBJECTIVES FOR THE SOLAR COOKER PROJECT

- Work in teams toward a common goal
- Collect data, analyze data and write analytically about data results
- Analyze a system to determine its efficiency/performance and understand what and how characteristics of the system impact efficiency/performance

Images l to r: Student notebook plan, selected parabolic curve, two example cookers







[Unit content and depth of progression towards course objectives for the Solar Cooker]

Unit 6: Intermediate Level CAD/CAM

Students use CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) and an iterative process, to develop and present a solution to a provided engineering challenge. Students include proper dimensioning standards and measurement tolerances to solution drawings and sketches. Students learn the process of iterative design, the use and application of measurement tolerances and proper part drawing dimensioning standards in order to CAD/CAM and then present a solution to a provided engineering challenge. The level of engineering challenge should be complex enough that initial efforts do not succeed, but rather inform the students what specifically should be improved to progress closer to success. Students should learn that failure is not deterministic, but rather an important part of the design process. Students experience the process of iterative design by building a "quick and dirty" first attempt solution out of provided resources (ex: hot glue and popsicle sticks). Students reflect on the successes and failures from the solution and then work to sketch, then design a solution in CAD software (ex: Solidworks). Once designed and approved, students use CAM (ex: 3D printer) to fabricate the part. Students then test, again noting what worked and what needed to be improved, and evaluate the final solution. Deliverables of the project are the final device and the documentation/discussion of the each iteration in the student's engineering portfolio.

Example project: Marble Maze Recirculation

Students work in groups of three to build a means of recirculating the ball bearings for our vertical marble maze. Students are provided the maze panels (from previous project results) and a powered circulating belt next to the maze. Students make their first solution system using popsicle sticks and hot glue. Through analysis of this first solution attempt, students learn what is critical and non-critical to the design challenge. Armed and guided by these understandings, students learn and apply the skills of CAD/CAM to build three or four iterations to their solution idea. At the end of the semester, students are tasked to circulate ten ball bearings through the maze as reliably as possible (in a given amount of time, if necessary). The deliverables for this project are the functioning device and the documentation/discussion of each iteration and the results in the student's’ portfolio.

TARGET COURSE OBJECTIVES FOR THE MARBLE MAZE RECIRCULATION PROJECT

- Work in teams toward a common goal
- Using sketching, measurement and CAD skills as tools to develop a design idea

Images (l to r). Bottom of the maze and the recirculation device/belt, top of the maze recirculation belt

Images l to r: Student 1st, 2nd and 3rd versions of ball holder for recirculation device

Unit content and depth of progression towards course objectives for the marble maze recirculation

Appendix A: Additional Example Projects

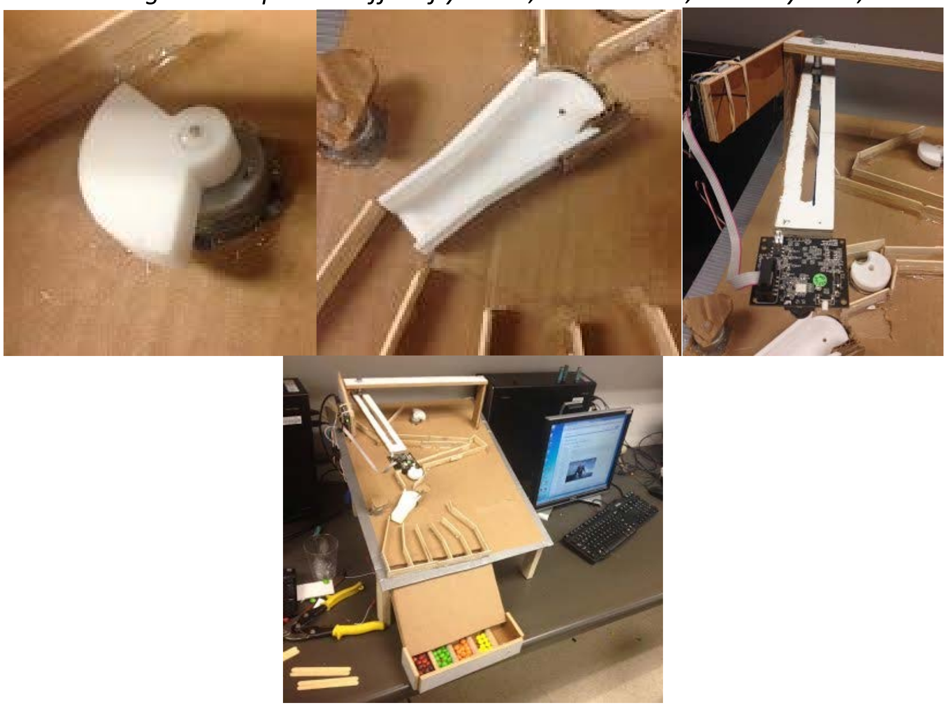
Additional Example project: Skittle Sorter

Students work in pairs to design, build and program a machine to sort 100g of Skittles by color as quickly and as accurately as possible. Students are provided with a Pixy camera that is capable of detecting and outputting color information. Students then must work to use this sensor to control a machine that captures all 100g of Skittles, feeds them individually in front of the Pixy and then sorts them into bins based on color. To succeed, students must use CAD/CAM to produce 3 parts: an offset flywheel that mates with a DC motor to provide vibration to the system in order to prevent jamming, an advancer wheel that controls the feed of Skittles and a sorter chute that guides Skittles into the desired bin. The first two are guided CAD/CAM activities requiring students to measure critical dimensions such as the DC motor shaft diameter and the Skittle size. These guided activities are scaffolded to support students so that the final CAD/CAM part can be fabricated independently.

TARGET COURSE OBJECTIVES FOR THE SKITTLE SORTER PROJECT

- Work in teams toward a common goal
- Collect data, analyze data and write analytically about data results
- Analyze a system to determine its efficiency/performance and understand what and how characteristics of the system impact efficiency/performance

Images l to r: 3D designed and printed offset flywheel, sorter chute, vision system, sorter machine



https://www.youtube.com/watch?v=kLjLgxFx9r4
https://www.youtube.com/watch?v=E52UA37azYI

Unit content and depth of progression towards course objectives for the Skittle Sorter