SOLAR CARS

In this apprenticeship students will engage in the engineering process to design, build, test, and revise a solar car according to the specifications set forth by the Junior Solar Sprint (JSS). Students will work in teams to apply their knowledge of solar power, vehicle mechanics, mathematics, and engineering to several iterations of a car design. Each iteration will be improved by rigorous testing and redesigned based on data. By the end of the apprenticeship students will be qualified to compete in the JSS. Some students may actually be able to compete in the JSS while others will compete against each other on campus.

Unit Standards and Objectives
21st Century Skill: Innovation

Innovation Standard #1: Citizen Schools students will generate an idea or product that suits a practical or artistic purpose
Lesson Objectives:
- Brainstorm a list of designs
- Compare the advantages and disadvantages of each design
- Select the best design based on the advantages and disadvantages of each

Standard #2: Citizen Schools students will use a design process to create ideas or products
Lesson Objectives
- List the steps in the design process
- Identify the tools and materials needed to realize your idea
- Create a plan for testing your design
- Improve your design based on data from testing

Standard #3: Citizen Schools students will realize an idea or product that suits a practical or artistic purpose
Lesson Objectives
- Build a solar car from a plan
- Rebuild a solar car from a revision plan
- Build your final solar car based on testing data

Project-specific Lesson Objectives:
- Trace the transformation of solar energy into kinetic energy in a car
- Explain the purpose and importance of solar car technology
- Display their car design/beginning building in a vlog entry and describe the materials and components using technical vocabulary
- Test your design
- Compile your vlog entries into a final Google Slides/PPT that showcases the design process that they learned throughout the class.

Essential Questions

How can I learn from designing, building, and revising a solar car?
Are there limits to how much I can improve my design?

Performance Task Assessment (WOW!)

The WOW! will showcase the solar car students created. The car can be showcased to a "panel of experts" and in a race (in JSS if it is available in your region, against each other if not). The solar cars will be powered only by solar energy. Students will demonstrate their knowledge of their cars and their design process to judges in a video log that can be shown on the day of the WOW! or at another time which will show their innovation skills. Students can be evaluated by the judges on creativity, speed, and design quality. Students will have been focusing on one of those three elements which will be weighted heaviest in their judging round.

Goal: Given limited materials and your understanding of car mechanics, you will use the design process to build a functioning solar car. In the process, you will document your design process using video logs.

Role: You will work as designers on a team to complete the brainstorming, construction, and revision of the car using the design process.

Audience: If competing in Jr. Solar Sprint, your car will be judged by other students and JSS judges. If not, your audience will include school selected judging panel and peers.

Situation: You will showcase your car on a race track in front of judges. Ideally you will be able to compete in a JSS or similar competition.

Product: You will build a solar car that is powered by an attached solar panel, and can complete a course that meets the standards of JSS competition. You will also create a weekly video logs of your process.

Standards: Your design will be assessed using the Innovation rubric and you will showcase each row through a vlog entry. On the day of the competition, you will be assessed based on creativity, speed, and quality (the JSS standards).

This task will be evaluated using the Innovation rubric found here.

Lesson Plans At-A-Glance

Lesson Plans are available here.

Week	Lesson Objectives	Agenda	Outcomes & Work Products
1	SWBAT trace the transformation of solar energy into kinetic energy in a car SWBAT list the steps of the design process SWBAT explain the purpose and importance of solar car technology	● Hook: Design Spotlight-Steps ● Introduction of New Material: What is solar energy? ● Activity 1: Design Process ● Activity 2: Solar Power and Energy ● Activity 3: Vlog ● Assessment: Exit Ticket	First vlog entry explains the purpose and importance of solar car technology; demonstrates students' ability to use the vlog process Exit Ticket questions: 1. What are the steps of the design process? 2. In the cars we are going to build, _______ energy is turned into _______ energy..
2	SWBAT brainstorm a list of designs SWBAT compare the advantages and disadvantages of each design; specifically the role of friction and the best gear ratios SWBAT select the best design based on the advantages and disadvantages of each	● Hook: Hill Racing ● Introduction to New Material: Friction ● Activity 1: Pit Crew ● Activity 2: Brainstorm designs ● Activity 3: Pick Your Path ● Assessment: Vlog Entry	Volg entry to share the design the group will pursue. Car Parts: Draft design for first iteration.
3	SWBAT display their car design/beginning building in a vlog entry and describe the materials and components using technical vocabulary SWBAT identify the tools and materials needed to realize your idea	● Hook: Design Spotlight-Gears ● Introduction of New Material: Ratios & Gears ● Activity 1: Investigating Ratios ● Activity 2: Reflection ● Activity 3: Redesign with Ratios ● Assessment: Exit Ticket	Vlog entry to share what gear ratio they want to use and why. Car Parts: Formal design for first iteration.
4	SWBAT build a solar car from a plan SWBAT create a plan for testing your design	● Hook: Design Spotlight- Great Gears! ● Introduction of New Material: Transmission Systems ● Activity 1: Precision & Accuracy-Teamwork ● Activity 2: Build Time ● Activity 3: Testing Plan ● Assessment: Vlog Entry	Vlog to predict car strengths and weaknesses including what data they will look for in tests Car Parts: First iteration of car.

5	SWBAT test their designs SWBAT compare the advantages and disadvantages of each design SWBAT improve their design based on data from testing	● Hook: What is Data? ● Introduction of New Material: What Are We Testing? ● Activity 1: Heat 1 ● Activity 2: Heat 2 ● Activity 3: Heat 3 ● Assessment: Vlog entry	Vlog to share the plan for redesign based upon the collected data. Car Parts: Formal design for second iteration.
6	SWBAT rebuild a solar car from a revision plan SWBAT use the design process and short term data collection to make an effective redesign.	● Hook: Design Spotlight ● Introduction of New Material: Spotlight on Design Process ● Activity 1: Redesign 1 ● Activity 2: Test 1 ● Activity 3: Redesign 2 and Test 2 ● Assessment: Vlog	Vlog Entry: What are the advantages of my new design over my old one? Car Parts: Second and third iterations of car.
7	SWBAT create a mount for the solar panel by evaluating several options for placement that meet race criteria and are effective at moving the car	● Hook: Design Spotlight ● Introduction of New Material: Spotlight on Solar Energy ● Activity 1: Solar Panels and JSS ● Activity 2: Solar Energy Test ● Activity 3: Solar Redesign ● Assessment: Go or No Go	Car that meets race criteria and is able to run on solar power Car Parts: Fourth iteration of car; adding the solar panels.
8	SWBAT redesign car for optimum voltage and solar panel placement based on testing SWBAT practice presenting cars using technical vocabulary learned in the class in a vlog	● Hook: Design Spotlight ● Introduction of New Material: Data & Your Car ● Activity 1: Solar Energy Test ● Activity 2: Build for Max Voltage ● Activity 3: Redesign for Voltage/Vlog ● Assessment: Vlog	Vlog that shares car using technical vocabulary Car Parts: Fifth iteration of car.
9	SWBAT build your final solar car based on testing data	● Hook: Design Spotlight ● Introduction of New Material: Aerodynamics ● Activity 1: Brainstorm ● Activity 2: Build for a Purpose ● Activity 3: Final Testing ● Assessment: Vlog	The final vlog entry will be an argument for why this final car design is the best design. Car Parts: Sixth iteration of car.
10	SWBAT compile their vlog entries into a final Google Slides/PPT that showcases the design process that they learned throughout the class	● Hook: Secret Awards ● Introduction of New Material: Creating a presentation ● Activity 1: Slide layout and inserting video ● Activity 2: Titles and Transitions ● Activity 3: Presentations ● Assessment: Celebration!	Should be able to rate all innovation rows Complete Google Slide/PPT Presentation Car Parts: Showcase final iteration of car.

Lesson Elements

Hook Opening ritual used each week to build excitement	While each lesson will have its own unique hook, in general each will do one of these things: 1. Take advantage of student misconceptions to open up questions they can answer for themselves during the lesson. 2. Give students a common experience from which the lesson can carry them forward. 3. Highlight a specific fact or concept that needs to be explored and/or addressed during the lesson.
Assessment How you will measure student learning (i.e., exit tickets, student writing, student presentations, etc.)	One of three assessment techniques will be used to close each lesson: 1. Exit Tickets will ask students to recall or explain one or two facts or concepts. 2. Vlog Entries will ask groups to present or explain a design, iteration, or to describe a concept in a short video. 3. Design Specs will be detailed drawings of groups' latest car designs.
Structures Learning structures, tools or student grouping strategies	Make student groups as small as possible given the amount of materials you can provide given your budget and access to existing materials. Ideally, student will not work alone nor will the work in groups larger than 4.

	Build Time and *Redesign Time* are included in most lessons to direct student work at the stations. The emphasis of *Redesign Time* is to plan or build a new or different way of accomplishing the design task, even if it worked the first time! The *Design Spotlight* each week features with new materials or a sketch in their notebook. During this time you can showcase successful design solutions from students in the class or previous solar cars.
Procedures Special procedures used each class (ie handing out folders, rearranging seating, etc.)	In every lesson there are specific roles and responsibilities for working with building materials at stations. One student from each group may travel to a station. Because there are materials that require safe handling, students should be reminded of expectations before using tools. **Station Set Up:** Generally, the seating arrangement should involve students working at desks and satellite building stations. You will want to include sets of materials at the stations, not at the student desks unless otherwise described. Discuss ways to make this effective at your particular site with your TL. For more on stations, see the last page of this plan. Materials procedures are critical for this class: In managing material, expect students to have a specific goal before they begin to do the building. This will keep them on task and help control crowding in the materials area.

Implementation Notes

Supplies Materials, tools, technology	The class is materials-heavy and more expensive. Check with your regional team about solar panels and motors but this is the basic set: http://www.solarmade.com/store/product/junior-solar-sprint-kit Additional materials like voltage meters, wheels, extension wires, smaller alligator clips, hot glue, wood/other base materials can be purchased from Amazon or your local hardware store. Budget will dictate how many students will need to be in a group, groups can be done by choice or by assignment. Ideally this happens during Lesson 1 but can happen during Lesson 2 if you want to poll students about preferences before making groups. PLEASE BUDGET for a kit for you as a teaching team so that you can build and play ahead of class starting. It is recommended that you build it together in training if possible to find sticking points that students will face.
Budget	Below is a list of materials with prices found on the internet. Better deals are possible with a little time spent searching.

Item	Cost	Quantity (Assuming 8 groups)	Supplier	Need
Carolina STEM Challenge Solar	$144.25	Provides materials for 8	Carolina	You need all the materials in this

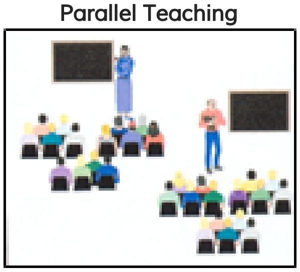
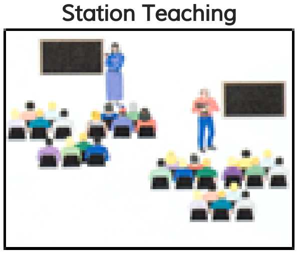
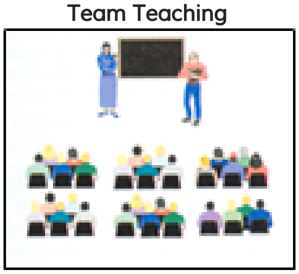
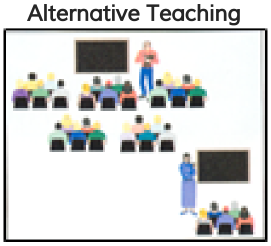
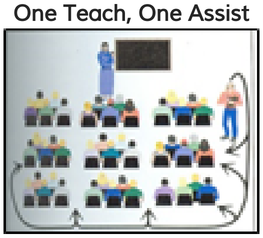
	Car Kit		cars		kit, but any kit that provides them will do.
	DC Motors 1.5 - 3 V	Included	8 provided	Carolina	
	Solar Cell, 1 V with leads	Included	8 provided	Carolina	
	Wheel, Gear, and Axle Pack	Included	8 provided	Carolina	
	Cardboard Pad	Included	8 provided	Carolina	Recycled cardboard would work too
	Drinking Straws (Axles)	Included	16 provided	Carolina	Easy to obtain elsewhere, sometimes at no cost
	Teacher's Manual	Included	1 provided	Carolina	Useful for images and design ideas, but not necessary
	Digital Multimeter	$37.00	8	Carolina	Necessary, but widely available; can share
	Wires with Alligator Clips	$11.35	2	Carolina	Necessary, but widely available
	Rulers	$1.00	8	Staples.com	Necessary, but widely available
	Scissors	$5.00 (3 pack)	3	Staples.com	Necessary, but widely available
	Transparent Tape	$10.00 (10 pack)	1	Staples.com	Necessary, but widely available
	Protractors	$0.49	8	Staples.com	Necessary, but widely available
	Flashlight	$7.99	8	Staples.com	Necessary, but widely available
	Hammers	$10.99	4	Staples.com	Necessary, but widely available; can share
	Pliers	$7.98	8	Lowes.com	Necessary, but widely available; can be shared
	Stopwatches	$10.15	2	Carolina	Necessary, but widely available; can be shared
	Construction	$6.79	1 pack of 200	Staples.com	Necessary, but

	Paper		sheets		widely available
	Poster Board	$17.99 (25 pack)	1	Staples.com	Necessary, but widely available
	Glue	$1.00	8	Staples.com	Necessary, but widely available; can be shared
	Paper Clips	$9.49 (1000 pack)	1	Staples.com	Necessary, but widely available
	Hobby Knives	$3.49	4	Staples.com	Necessary, but widely available; can be shared
	Incandescent Desk Lamps	$9.63	4	Walmart.com	Necessary, but widely available; can be shared
	TOTAL COST:	$786.64			

Supporting Materials & Resources handouts, books, materials	Slides for each lesson that you can customize are available here. If you are working with JSS, please refer to their official website and rules for additional information: http://www.usaeop.com/programs/competitions/jss/ If your teaching team is not well versed in this content you might want to consider purchasing the curriculum from here ($35): https://www.teachengineering.org/view_activity.php?url=collection/duk_/activities/duk_solarcar_tech_act/duk_solarcar_tech_act.xml A great, free resource to help guide the process: http://www.nrel.gov/docs/gen/fy01/30828.pdf
Location Tables/desks, or classroom, gym, kitchen, outside, etc.	You will need to determine the surface that students are going to race on (indoor/outdoor, smooth, rough, etc.) and plan for access on testing days.
Choice and Voice Key decisions students make	Students will make choices around design and improvements which *may* alter the materials you need for this apprenticeship. The course of the lessons should not change, however.
Modifications for Student Needs Supports and changes to help meet the needs of all learners	For students with processing difficulties, watch their trials closely so that you can help them make connections between what they see and any improvements they can make. Students with physical impediments to fine-motor skills should be allowed extra time. Avoid "doing it for them" whenever possible. It will be better that these students get to do the physical work themselves even if it costs them one cycle of trial and revision. If there are students with acute behavioral challenges consider keeping them close together (even if they are not in the same group) and adjust your co-teaching strategy so that one of you is working closely with them, keeping them on task, and redirecting them when necessary. Every effort should be made to give these students the same experience as typical students. If there are ELL students in your class and either you or your co-teacher have experience with ELL and/or speak the same language, adjust co-teaching to take advantage. If neither of you have experience with ELL or speak other home languages, consider taking the time to provide written instructions translated via online translator ***and where possible*** checked by a native speaker of the translated language.

Student Background Knowledge and Skills Needed Academic skills, social emotional skills or developmental milestones needed	Students should have positive experience working in groups and be able to problem solve.
College and Career Readiness Connections to college and career	This is an introduction to the kinds of problem solving students will encounter in STEM college courses. In addition to careers in the automotive industry, this apprenticeship introduces students to the type of work done by mechanical engineers and by the energy industry.
Co-Teaching Roles Recommendations for co-teaching and planning	This apprenticeship will rely heavily on the Stations co-teaching model, though there will be some Parallel Teaching and One Teach, One Assist.
Special Resources Field trips, excursions, guest speakers	The need for field trips or guest speakers for this unit is not urgent, and it will take away from the number of iterations students can make with their cars. However, if an mechanical or solar engineer is available and can help students in a way that is specific to making their cars better, consider reaching out and asking them to do so as a guest. Keep in mind, having someone who works in a related field come in and "give a talk" may not be the best use of students' time - having someone come in to talk about installing solar panels on houses, for example.
Road Map to WOW! Visual overview for students of their 10 week apprenticeship	Note to CT/TL: Create a poster-sized visual of the information listed below, display and reference weekly in your classroom. Visual overview for students of their 10 week apprenticeship: Week 1: Meet the group, learn about solar power, and explore different car designs. Week 2: Decide on one design from your own list of choices. Week 3: Design the car and plan how you'll build it. Week 4: BUILD DAY – motor, gears, base, and wheels together to get a car that can move with a battery; plan how you'll test it. Week 5: TEST DAY – run the cars and collect data on: sturdiness, distance, speed, and straightness. Decide on adjustments. Week 6: Rebuild and re-test your car. Week 7:Solar Panel and payload attachment Week 8: Test cars using their solar panel structure Week 9: Final adjustments and making sure cars meet intended focus Week 10: Create process vlog using PPT template WOW! Poster Examples: Example 1 Example 2 Example 3

Co-Teaching Structures Guide

Teaching Model	Description	Why should we use it?	When should we use it?
Parallel Teaching 	Class is split into two (or more) small teams. Same content is taught to each team.	·Low student-teacher ratio ·Greater proximity to high-risk students ·Co-teachers have equal presence and responsibility in the classroom	·When we can plan effectively together to ensure we teach the same content to each group well. ·Classroom's physical structure permits it. ·For lessons with heavy independent work ·Need to provide a lot of individual attention
Station Teaching 	Class is split into two (or more) small teams. Different material taught to each group simultaneously and then teams switch or teachers switch.	·Low student-teacher ratio ·Co-teachers have equal presence and responsibility in the classroom. ·More variety in teaching methods for teachers and students	·When a lesson can be split into two mutually exclusive and equally timed parts (e.g. using a camera/critiquing a photo, chopping vegetables/measuring ingredients) ·When the classroom's physical structure permits it ·For lessons with a lot of knowledge or skill-building
Team Teaching 	Both teachers actively teach the material taking turns during the lesson to lead teach. While one teacher is lead teaching the other goes around to groups or individual students.	·One teacher can pay attention to high-risk students while one teacher leads the full class. ·Co-teachers have equal presence and responsibility in the classroom.	·When it's difficult to effectively split a lesson into two stations ·When a lesson has lectures and independent practice time ·If most SPED students can follow whole-group instruction ·Best used with well-developed co-teaching relationship ·For lessons with a lot of group work
Alternative Teaching 	One teacher remediates a small group of students (pre-teach, re-teach, supplement, or enrich) and catches them up for the main lesson being taught by the other teacher.	·Low student-teacher ratio. ·To remediate in class for a small group of students. ·To catch students up who may not have understood/missed previous lessons	·When the benefits from a few minutes of remediation/ pre-teaching will pre-empt greater misunderstandings for the lesson. ·When the classroom's physical structure permits small group in one part of the room. (CTs should not be left alone in the classroom with students.)
One Teach, One Assist 	One teacher lead teaches the whole lesson and the other teacher works with individual students.	·To redirect behavior from an especially low functioning student. ·To pay greater attention to a student who needs one-on-one interaction in order to keep up	·If there is a particularly high-needs student(s) in the classroom that need specific support. ·During direct-teach sections of the lesson

The Pitch

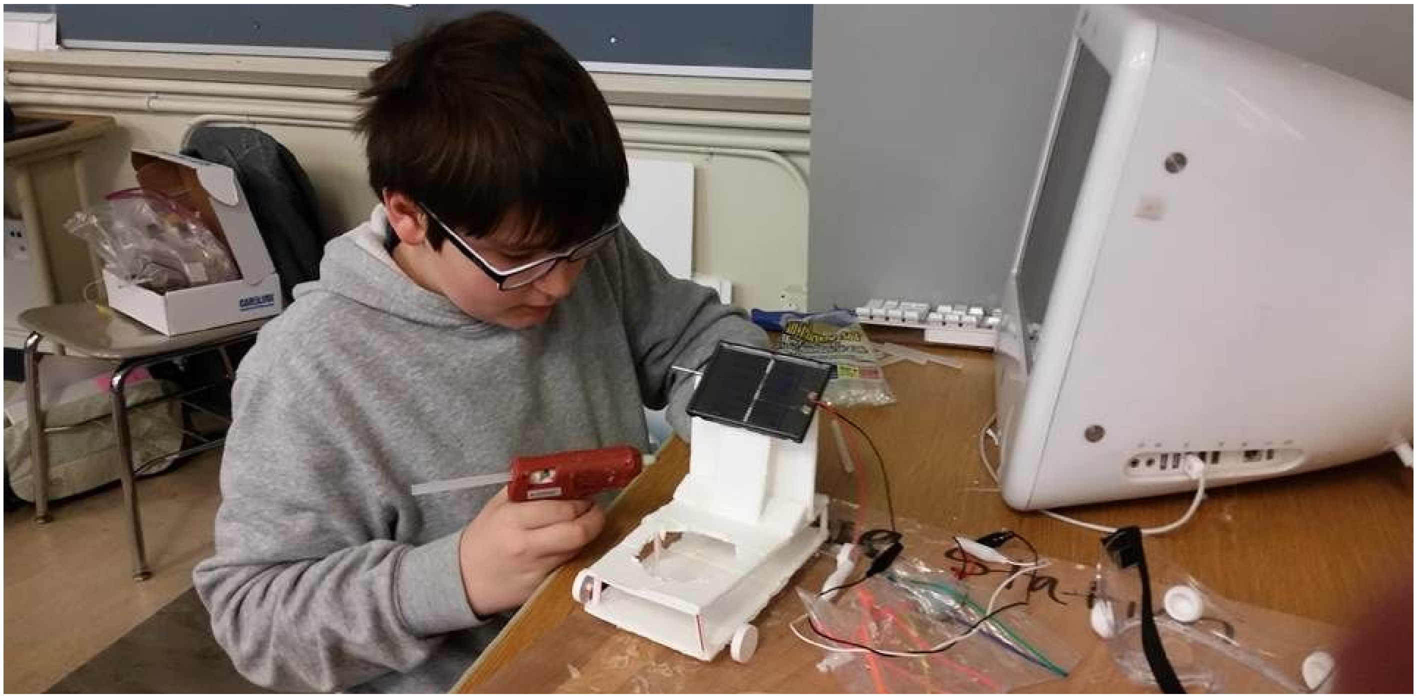
Come prepared with two charged solar cars. The two should be identical except for the gear sizes which should be hidden from sight on the car. Ask students which car they think will win (perhaps paint numbers on them to differentiate). The car with the better gear ratio will win, but students will not see the gears. Ask them why they think that car won. Get them excited with a fast pace peppering of questions "Why do you think this one won? Why do YOU think it won? How about you? And you? You? YOU?" Don't give any hints. Hook them in by closing with "This car won because it was designed better. If you want to know how, you will probably LOVE this apprenticeship!"

Materials Needed for Pitch Day

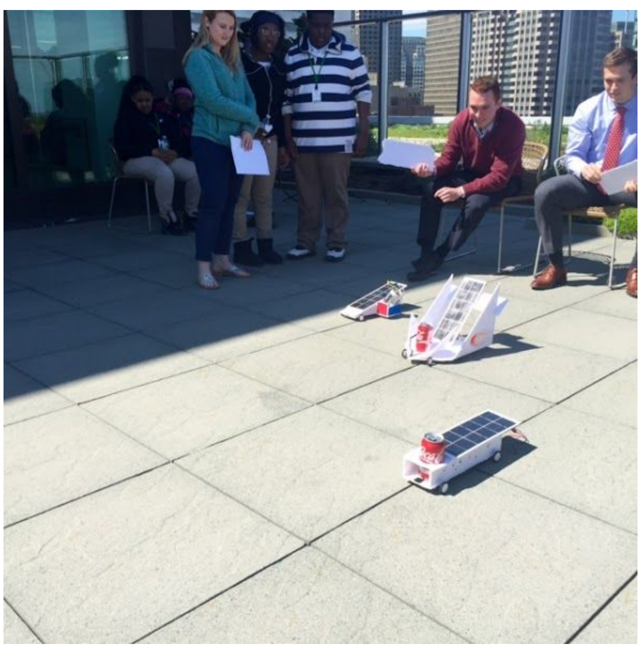
1. Solar car with a 1:1 gear ratio.
2. Identical solar car with a 2:1 gear ratio.
3. Finish Line (consider constructing some kind of checkered flag overhang).

Apprenticeship in Action

Students in Salem prepare to test their car



Collins Middle School student works on his team's car at the glue station



Students test their cars

Students on race day at JSS in MA

"Students from the Trotter Innovation School this semester created solar powered cars with their volunteers. While most students just focus on getting the car to move across the race track, this group of students created "the beast" as it was nicknamed at their WOW! The group created aerodynamic wings to help the car move faster and ended up getting to the final round of their race!" - Citizen Teacher, 2016

Apprenticeship Description for WOW! Communications

In this apprenticeship students will engage in the engineering process to design, build, test, and revise a solar car according to the specifications set forth by the Junior Solar Sprint (JSS). Students will work in teams to apply their knowledge of solar power, vehicle mechanics, mathematics, and engineering to several iterations of a car design. Each iteration will be improved by rigorous testing and redesigned based on data. By the end of the apprenticeship students will be qualified to compete in the JSS. Some students may actually be able to compete in the JSS while others will compete against each other on campus.

Apprenticeship Acknowledgements

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Resource: Station Descriptions

Reference station: provides examples of different kinds of cars and transmissions.
Cutting station: all cutting takes place at the cutting station.
Note- Knives are not to be removed. All cutting must occur on top of cardboard, with the object lying flat. Blades must be retracted when finished.
Sawing station: *Note: apprentices will wear safety goggles when sawing. The clamp must be used at all times. Apprentices who abuse this station will be asked to go to the "pit stop" station.*
Pit stop station: (time out) with puzzles and reference materials.
Gluing station: where all gluing will happen. Use glue gun with caution.
Painting station: all paint stay here.
Pliers and Rulers station: Tools for measuring and bending.
Bearings and Wheels station: tools for building and redesigning wheels and attachments.
Chassis materials station: Includes tools for building and restructuring chassis (except glue).

Sample Set Up: