The Design Process

Objective

Students will use the design process to create an initial design for a solar-powered car.

Materials

Design Process handout

Procedure

1. Briefly review the components of a solar car about which students will be able to make design choices: solar panel, chassis, wheels, axles and bearings, transmissions, body shells.

2. Distribute a copy of the Design Process handout and review it with students. To give them a general overview of where and when they will apply the steps of the process in making their Junior Solar Sprint cars, highlight the following points:

⑤ **Define Goals and Objectives**

To begin with, a designer needs to clearly define the problem: what is the **goal** of the design, and what **constraints** exist that will provide limits for the design.

Some possible **goals** for the design of the solar car are:

• To make the race-winning model solar car

• To make a stylish model solar car

• To make a sturdy, robust solar car.

Constraints are the limitations that are imposed upon the design by the designer or by the problem itself. In designing a model solar car some **constraints** imposed by the designer might be:

• Materials will cost less than $20 and be easy to find

• The car must be constructed in eight weeks

In addition, there might be **constraints** imposed by the rules, such as:

• The car must be powered only by a solar panel and a motor provided in a kit

• The car must be within the specified size limits

• The solar panel cannot be a structural member of the car

Defining the goals and constraints helps focus the designer's time and effort on the most important areas.

⑤ Generate Ideas

Design relies on generating ideas. **Brainstorming** is an effective idea-generating technique that is usually done in groups. The goal of a brainstorming session is to generate as many ideas as possible in the given time. The duration of brainstorming sessions varies with the quantity and complexity of the issues to be discussed, but for a student group such as this a session lasting from 15 to 30 minutes is recommended. Students can begin with brainstorming ideas for car components.

Some possible topics for **brainstorming** sessions are:

- Types of transmissions
- Ways to attach a solar panel to the car
- Aerodynamic body shapes
- Materials for wheels, axles, and bearings

To make these sessions productive, it is useful to set a few ground rules. One of the most important is "There is no such thing as a dumb idea." Participants are encouraged to contribute ideas they consider silly since these ideas may trigger more practical ones in their own or another participant's thinking. Another useful rule is “withhold criticism.” Focus on generating as many ideas as possible and be sure to record all the ideas.

Students can also generate ideas outside of brainstorming sessions. A skillful designer combines new ideas with existing ones, or combines existing ideas in innovative ways. To stimulate the generation of ideas and to increase the awareness of existing technologies, students should examine related mechanical devices such as toys and small appliances. How did other designers solve problems similar to those in model solar car design (wheels, bearings, transmissions, chassis, etc.)? What parts can be used or where can similar parts be found? Reference books such as David Macaulay’s *The Way Things Work* or *The New Way Things Work*, or user's manuals for various appliances may be consulted for ideas. Trips to hardware stores, hobby shops, craft stores, and other creative places to look at various tools and gadgets are also good ways to get ideas. A good designer sees to it that he or she has a wide variety of ideas to choose from.

⑤ Investigate Ideas

Once the ideas have been generated, students will be wondering how to choose between all of these concepts. They should be encouraged to formulate questions and experiments that will help to answer them. There is a natural tendency to go for the ideas one likes best or has a "gut" feeling for. These concepts may indeed be the ones that work out best, but unless they are tested against other concepts, the designer can never be sure that all ideas were investigated fully and the best design was selected.

There are many ways to investigate ideas, such as research and consulting with experts, but the most direct and convincing way is to try it out for oneself. This is the essence of hands-on design. Often the design is broken down into smaller problems, which are investigated individually. In the case of a model solar car, the smaller problems are the individual mechanical components (wheels, transmissions, chassis, etc.). Some possible investigations to undertake are:

- What are good ways to build wheel axles and bearings?
- What is the effect of weight on a vehicle?
- How can a simple transmission be built from low-cost parts?
- What car body shapes have the lowest aerodynamic drag?

The investigations called for here are likely to be simple experiments where students get a feel for the mechanical concept behind their question. A complex investigation may be broken up and assigned to different groups or individuals; their results can later be shared with the entire class. A student investigating materials and methods for building a car chassis, for example, may take simple pieces of each material and watch how they react to various loads or forces. Another example may be to build various transmissions on a simple chassis (not necessarily the one they intend to use in their final car) and compare their relative performance and ease of construction. As part of this process, students should identify design variables, that is, attributes that can be varied to affect performance.

Some of those **design variables** are:

• Transmission ratio

• Wheel diameter

• Vehicle shape

• Material selection

The goal of these investigations is to gain an understanding of all the individual parts of a vehicle. The groups will probably have a few concepts for each component; they will be narrowed down in the next phase.

⑤ Compare Concepts and Select Design

Designers compare concepts or do "trade-offs" of alternative component designs throughout the design process. They weigh the various ideas against the design criteria and see which ones come out best. Much of the time the designer does this in his or her head. However it is often helpful, especially when working with a group or a complex problem, to write down the pros and cons of each idea.

Some examples of **pros and cons** for a particular transmission design (a gear drive in this case) are:

Pros	**Cons**
• Reliable	• Harder to build and align properly
• High efficiency	• Harder to find meshing gears
• Won't slip	• Harder to modify ratio

In addition to presenting all relevant information in a single place, the record of ideas also allows the designer to go back later and choose another design if the first one selected does not work out.

Once designs of individual components have been evaluated and one or two leaders identified, students can begin to integrate them into a complete car design. The design for the complete car will be a combination of the students' most workable components. The deciding factor in the choice between two or more workable options for a particular component may be its compatibility with the rest of the car's design. If concepts generated thus far are not sufficient, it may be necessary to refer back to the brainstorming notes and/or generate more ideas.

⑤ **Build**

This is the step where the design becomes a reality. Your design should take into account the materials and tools required to produce your car. Be sure to use proper safety procedures and equipment when working on your car and remember that it must be able to stand up to the rigors of racing. Thorough prototyping of components helps the final vehicle construction go smoothly. Parts built for experimentation may also be used in the final car design and construction. Building usually takes more time than you think, so be sure to leave extra time. Plan to finish well before any deadline.

⑤ **Test**

Once a car is built it needs to be tested to see if all the components are working together to accomplish the goals and meet the constraints placed on the design. Setting up measurable tests is an important part of the design process so that as adjustments are made to the car or its components the designer can determine if the change was beneficial or detrimental. If you find a major problem during testing you can return to the generate ideas step or look at some of the options you had during the compare and select step.

The testing phase is an appropriate time for the class to discuss performance measures. Some **performance measures** for the complete car include:

- Time to go 20 meters
- Rolling resistance and aerodynamic drag
- Total vehicle weight
- Acceleration
- Top speed.

A long hallway or track and guide wires are useful for vehicle testing. Since solar power may not always be available for testing the vehicle, alternative power sources will be required. A ramp may also be set up for "roll down" tests (motor must be disconnected from transmission) to test rolling resistance and aerodynamic drag.

⑤ Optimize

Once you have constructed your car and performed some testing you will want to make adjustments to optimize performance. Some ideas for this process include:

• Try to identify the source of any problems.
• Compare your car to prototypes you have constructed.
• Evaluate how long it will take to make corrections.
• List out your options with pros and cons, then determine what to do and do it.
• Re-test your car after any change to see what the change did.
• Only make one change at a time.

Experienced designers know that the process of optimization involves trade-offs, because optimizing one variable may prevent you from optimizing another. For example, a frame that is both stiff and light may be desired, but stiffer frames may be heavier. Another classic example is the transmission ratio: a car with high top speed takes a long time to accelerate. Taking the time to optimize the car will often improve the performance dramatically.

Remember that as components are optimized the car must be tested again to see the overall effect of the change. This will return you to the test step of the process and requires measurable testing to compare.

⑤ Final Product

The final product will be the result of all your hard work. You may be able to make adjustments to your vehicle between races, but remember that the car must be ready to run at race time—the starter will not wait for you to make adjustments. Think through the possible adjustments you will need to make and prepare for them as you go through the steps just completed. Make sure everything is ready by testing all your designs.

3. Part of the challenge in design is learning to combine good ideas from several people into a winning design. Place students in small groups of two or three people. Instruct students to use the design process to create initial concepts for a solar-powered car that moves as quickly as possible on a flat surface and should be no larger than a shoebox. Students should consider the design of the chassis, wheels, axles and bearings, transmissions, body, and the solar energy source. Encourage them to write down or sketch all their ideas for future reference and to generate a list of questions they need to answer as they proceed.

4. Have each group present its best design solution for a solar-powered car. This should be the design they will begin testing in the next phase of this process. As they are presenting their designs, have them specifically address their ideas for the design of the chassis, wheels, axles and bearings, transmissions, body, and the solar energy source. Allow students from other groups to ask questions about their design choices and offer suggestions.

5. Have each group meet together after the design presentations to draw up a list of ideas for how they will begin testing and evaluating the various elements of their design to create their final products.

Source: Design process materials created by Rick Butchart for the Chimacum School District in Washington; used with permission.