### Crutches Carry Caddy Project Resources

### Vocabulary/Definitions

*[assistive device:](https://en.wikipedia.org/wiki/Special%3ASearch?search=assistive+device" \t "_blank)* A device designed or adapted to help people with physical or emotional disorders to perform actions, tasks and activities.

*[biomedical engineering:](https://en.wikipedia.org/wiki/Special%3ASearch?search=biomedical+engineering" \t "_blank)* The application of engineering principles and techniques to the medical field.

*[design:](https://en.wikipedia.org/wiki/Special%3ASearch?search=design" \t "_blank)* (verb) To plan out in systematic, often graphic form. To create for a particular purpose or effect. For example, to design a building or a device. (noun) A well thought-out plan.

*[disability:](https://en.wikipedia.org/wiki/Special%3ASearch?search=disability" \t "_blank)* A physical or mental condition that limits a person's movements, senses or activities; a handicap.

*[engineering design process:](https://en.wikipedia.org/wiki/Special%3ASearch?search=engineering+design+process" \t "_blank)* A series of steps used by engineering teams to guide them as they develop new solutions, products or systems. This is a cyclical process that requires engineers to test and redesign prototype devices as often as it takes so they end up with reliable finished products.

*[fastener:](https://en.wikipedia.org/wiki/Special%3ASearch?search=fastener" \t "_blank)* Something that holds or joins two or more materials together.

*[material:](https://en.wikipedia.org/wiki/Special%3ASearch?search=material" \t "_blank)* The substance or "stuff" from which something is made.

*[problem solving:](https://en.wikipedia.org/wiki/Special%3ASearch?search=problem+solving" \t "_blank)* The process of working through details of a problem to create a solution.

*[property:](https://en.wikipedia.org/wiki/Special%3ASearch?search=property" \t "_blank)* A quality or trait belonging to an individual or thing.

### Procedure

**Background**

The focus of this design project is the application of the engineering design process (EDP) in order to develop prototype assistive devices to meet a specific design challenge. Thus, teachers should have a good working knowledge of the EDP in order to prepare students adequately. The EDP framework provided in the [Steps of the Engineering Design Process Visual Aid](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_edp_visualaid.pdf%22%20%5Ct%20%22_blank) is from the Massachusetts curriculum frameworks, but many other versions of the EDP are suitable. Throughout the activity, have student groups closely follow the EDP steps.

This design project requires the use of a general fabrication shop or, at a minimum, an assortment of hand and power tools to support students' designs and material choices.

It is helpful if teachers have some knowledge of material properties in order to guide students when questions or problems arise during the materials selection stage of the project. Likewise, having a general knowledge of the various kinds of fasteners available is also helpful since students will need to determine ways to securely fasten their completed devices onto the crutches.

Make students aware of pertinent terminology. **Materials** are the substances or "stuff" from which items are made. A materials **property** is its quality or trait. **Example materials properties** include: rough, smooth, hard, soft, strong, flexible, brittle, rigid, elastic, conductor, insulator, heavy, light (weight), durable, inexpensive. For example, glass is fragile, and something brittle is easily damaged or destroyed. When designing something new, good material choices are those selected because they have physical properties that support the purpose of the item and the conditions the item will encounter.

**Fasteners** are items that hold or join together two or more materials. **Fastener examples** include: nails and screws, nuts and bolts, clamps, clips, pins, staples, hook and loop (Velcro), tape, twist ties, and zip ties. While glues and tapes are considered adhesives, they also may serve as fasteners to hold or join materials together.

**Before the Activity**

* Gather materials and make copies of the [EDP Pre-Activity Test](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_pre-post-test_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank), [Assistive Device Project Research Handout](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_deviceresearchhandout_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank), [Materials Properties Research Handout](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_materialsresearchhandout_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank), and [EDP Post-Activity Test](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_pre-post-test_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank), one each per person.
* Prepare the following attachments either as PowerPoint slides or student handouts: [Steps of the Engineering Design Process Visual Aid](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_edp_visualaid.pdf%22%20%5Ct%20%22_blank) and [Project Design Criteria](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_criteria_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank).
* If showing PowerPoint slides, have a computer and projector ready to use.
* As examples to show students, gather together an assortment of materials or fasteners that you anticipate students might need during the project, such as the suggestions in the Materials List. If you do not have access to a wide variety of materials or fasteners, prepare an example list of them from which students can consider and choose. In addition, decide whether or not to permit students to bring in their own materials.
* Have available a pair of crutches for students to examine in order to help get ideas flowing right away.
* If desired, determine in advance how to divide the class into work groups of two or three students each.
* After Day 3, be ready to go shopping to make all reasonable material requests available for students.

**With the Students—Day 1**

1. Administer the pre-activity test, which asks students to place the steps of the engineering design process in the correct order (this same test will be given post-activity).
2. Then review and/or introduce the steps of the **engineering design process**(EDP), referring to the visual aid as necessary. Direct students to copy the steps into their notebooks. The basic steps are: identify the need or problem, research the need or problem, develop possible solutions, select the best possible solution, construct a prototype, test and evaluate the prototype solution, communicate the solution results, redesign as necessary. The process is cyclical and may begin at, and return to, any step.
3. Introduce the engineering challenge to the class by presenting the Introduction/Motivation content.
4. Use the Project Design Criteria to present the problem statement: **Design a device to enable a person on crutches to carry books and small objects**.
5. Connect the problem statement to the EDP step 1: identify the need or problem. Explain that it is important to clearly identify the statement of need before design can begin.
6. Use the Project Design Criteria to introduce the project **constraints**. Direct students to copy the constraints into their notebooks. The device must:
* Be safe to use.
* Weigh less than 2 pounds (~1 kg).
* Carry a minimum of 4 pounds (~2 kg).
* Attach to a pair of crutches (or an individual crutch).
* Be completed in three weeks.

**With the Students—Day 2**

1. Divide the class into work groups of two or three students each.
2. Tell students that they are beginning step 2 of the engineering design process: research the need or problem.
3. Direct students to use computers with Internet access to complete the two guided research handouts. What they learn from the research is important and relevant because as they begin working on their designs, ideas and decisions about materials will be based partly on the physical properties of specific materials. Project constraints will also drive decisions about materials, for example, heavy, brittle and unsafe materials should not be selected.

**With the Students—Day 3**

1. Students begin EDP step 3 to develop possible solutions by brainstorming and designing possible carrying devices. Remind them to make no final design decisions right away; this is the time for groups to explore and build off ideas contributed by every team member (called brainstorming), discuss the pros and cons of functionality and materials, and agree as a team on a final "best" design solution that meets all the constraints (EDP step 4: select the best possible solution).
2. Have groups create drawings of their devices (perhaps at half-scale) that include descriptions such as dimensions, materials and fasteners.
3. As students begin to consider and identify materials for their prototype devices, direct them to list the materials required by their designs, including details of how many or how much for each item. Have students calculate the total amount of material(s) to be used in their designs. For example, have them weigh a known amount of a material (such as a 2-in2 piece of polycarbonate) to determine its weight per area amount, and do this for all materials (cardboard, aluminum, wood, etc.). From these amounts, they can estimate the weight of their prototype devices to make sure to stay under the weight constraint and to know how much material(s) is needed.
4. Have groups meet one-on-one with the teacher to review the plans (drawings and lists) for their devices. Give design approval to affirm that final designs meet the constraints.

**Note:** Consider your available supplies and/or shopping restrictions. Make every attempt to provide all reasonable material requests for students. If designs do not meet all the constraints or require unreasonable materials and unavailable tools, direct students to steps 3-4 to rethink the design possibilities and prepare a revised "best" design.

**With the Students—Day 4**

1. Have groups continue designing and/or begin building their prototypes (EDP step 5) once all plans to meet the design criteria are satisfied.
2. Provide safety guidelines and instructions for correct use of tools and equipment as necessary, since not all groups will use all resources. Remind students using power tools to wear safety glasses and/or ear protection.
3. Work with the student groups to review/approve designs as they develop.
4. Verify that a design meets the weight constraint by having students weigh the final materials, fasteners and other components before attaching them to a crutch. Depending on the tools available, students gain new skills while creating their prototype devices. This student prototype-carrying device was zip-tied to a crutch.

**With the Students—Days 5-10**

1. Have groups continue to build the prototypes and move into the test and evaluation phase (EDP step 6) during which they evaluate and improve their prototypes to best meet the design criteria. Part of this step includes determining what sorts of tests and measurements to conduct in order to evaluate and evolve the prototype design. Expect students to create and implement logical test and evaluation ideas. If guidance is needed, refer to the ideas provided below:
* Test to see how much weight the device can hold, using weights and actual items.
* Verify that a design meets the weight constraint by weighing the final device materials, fasteners and other components before attaching them to the crutch.
* Once attached to a crutch, load the device with 5 pounds (~2.3 kg) of weight, then use the device to determine the efficiency of design.
* Loaded with weight, does the crutch(es) hold the device securely with the chosen attachment method? For example, sometimes the choice of string, rope or tape to attach devices is not strong enough to prevent devices from swinging during use.
* Is the device located on the crutch(es) so that it does not create problems during use? For example, a device located too low on a crutch can create a pendulum effect, making it difficult to walk.
1. Ongoing evaluation of designs against the objectives and constraints is essential. Expect prototype testing and evaluating to result in ongoing modifications to the original designs. Much can be learned by testing, so encourage students to make calculations and do many rigorous tests. Direct students to take notes to document their tests, results, observations and evaluations, which helps during the design process so they can refer to them for clarification as the design evolves and improves. In addition, the results from evaluations can suggest modifications that are worthwhile redesign ideas.
2. Support the groups by acting as a lab monitor to help with supplies and materials, assist with and troubleshoot any problems that arise, and monitor student use of tools, machines and the shop area.
3. Expect groups to finish their prototypes at different times due to the variations in design complexity and focus.
4. As the prototypes are completed, evaluate them against the original constraints. Use the suggested rubric for grading. Use a scale to measure the device weight and the weight carried. Observe the device in use to judge its effectiveness and safety.
5. Have students take photographs of their finished prototype devices, both in use by students and with close-ups of key features.

**With the Students—Day 11**

1. As step 8 of the engineering design process, ask groups to develop at least one "redesign" alternative solution that would provide improvement or additional features. Often, good ideas for redesigns (or entirely different design solutions) come from the testing and analysis stage, so prompt students to think back to what they learned and observed during testing (suggest they refer to their notes from days 5-10). Mark or identify the design alternatives on the original design sketches.

**With the Students—Days 12-13**

1. As EDP step 7 (communicate the solution), direct groups to prepare presentations that communicate project results. Require presentations to follow the steps of the engineering design process, for example: title slide, identify problem, recap research, show design solutions, remaining suggestions for improvement, etc. Include sketches and photographs.
2. Have groups show their presentations at project end, or invite families to an "Engineering Night" or end-of-day "Design Expo" to showcase their work.
3. Administer the post-activity test, as described in the Assessment section.

### Assessment

**Pre-Activity Assessment**

Pre-Activity Test: Administer the [Engineering Design Process Pre-Activity Test](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_pre-post-test_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank), which asks students to place the steps of the engineering design process in the correct order.

Think-Pair-Share: Ask student pairs to share what they know about how they, or someone they know, managed to get around on crutches and what they did to carry things. Randomly select groups to share their experiences. Discuss ideas as a class.

**Activity Embedded Assessment**

Spot Check Questioning: During Days 3-13, as students work through the EDP steps, spot check their comprehension of the objective/problem statement, project criteria/constraints, and where they are in the design process. Example questions:

* Why is it important to identify the problem? (Example answers: It gives focus and clarity to the process of design and problem solving. It drives all decision making during the design process.)
* What is the purpose of a prototype? (Example answer: It is a model that can be tested to see if the design functions as intended. You can learn a lot from failures. Usually it takes many prototype "iterations" to obtain a good design.)
* How do you know if a design works? (Example answer: It achieves the stated objective and does not violate any of the constraints.)

Tests & Evaluations: While students are building their prototype designs, their ongoing testing and evaluation serves as assessment of the success of their design work in meeting the objectives and constraints, as well as a measure of their engagement in the project. Encourage students to do many tests, such as determining how much weight the device can hold and how fast a person can "crutch" (that is, walk with crutches) with a weighted device. Conducting rigorous tests and collecting comparative data on interim and alternate designs helps to clarify the results. If desired, collect and review students' notes on their tests and results.

* As a class, create a graph of device weight vs. maximum amount of weight that the device can hold (for each group). Then discuss the trade-offs that are made for each type of device (i.e. a lighter device is easier to carry around but can't hold as much weight, whereas a heavier device can carry more weight but isn't as easy to carry on crutches).

**Post-Activity Assessment**

Prototype Evaluation: Use the [Carrying Device Project Rubric](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_rubric_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank)to assess groups on their completed devices against the three project learning objectives: 1) solution solves an open-ended design problem, 2) student applied engineering design process, and 3) student developed multiple solutions.

Post-Activity Test: Administer the [Engineering Design Process Post-Activity Test](https://www.teachengineering.org/content/wpi_/activities/wpi_crutches_activity/wpi_crutches_activity_pre-post-test_v2_tedl_dwc.pdf%22%20%5Ct%20%22_blank) (same as the pre-activity test), which asks students to place the steps of the engineering design process in the correct order. Compare students' pre/post scores to gauge their mastery of the concepts.

### Activity Scaling

* For upper grades, more advanced students or classes with access to computers with CAD software, have students create their design drawings or plans using a 3D modeling program such as Google SketchUp.
* To heighten the challenge for more advanced students, add a materials budget (a cost limitation) in addition to the safety, weight, load and time constraints.
* If a machine shop is available for student use, scale up the project materials, skill-building fabrication instructions and prototype quality expectations to take advantage of the more advanced tools.