# Technological Problem Solving

There is a difference between science and technology. The goal of science is to understand the natural world. The goal of technological problem solving is to develop or revise a product or a process in response to a human need. The product or process must fulfill its function but, in contrast with scientific problem solving, it is not essential to understand why or how it works. Technological solutions are evaluated based on such criteria as simplicity, reliability, efficiency, cost, and ecological and political ramifications.

*Even though the sequence presented in the graphic below is linear, there are normally many cycles through the steps in any problem-solving attempt.*

## Process Description

**Defining the problem**

**This process involves recognizing and identifying the need for a technological solution. You need to clearly state the question(s) that you want to investigate to solve the problem and the criteria you will use as guidelines and to evaluate your solution. In any design, some criteria may be more important than others. For example, if the product solution measures accurately and is economical, but is not safe, then it is clearly unacceptable.**

**Identifying possible solutions**

**Use your prior knowledge and experience to propose possible solutions. Creativity is also important in suggesting novel solutions.**

**You should generate as many ideas as possible about the functioning of your solution and about potential designs. During brainstorming, the goal is to generate many ideas without judging them. They can be evaluated and accepted or rejected later.**

**To visualize the possible solutions it is helpful to draw sketches. Sketches are often better than verbal descriptions to communicate an idea.**

**Planning**

**Planning is the heart of the entire process. Your plan will outline your processes, identify potential sources of information and materials, define your resource parameters, and establish evaluation criteria.**

**Seven types of resources are generally used in developing technological solutions to problems—people, information, materials, tools, energy, capital, and time.**

## Example: Inventing a pH Meter

**Defining the problem**

We often need to solve technological problems before we can conduct a scientific investigation. For example, imagine that you are asked to conduct an investigation in which you cannot, for safety reasons, use the traditional, commercial pH indicators. Your task, then, is to design a safe chemical indicator for pH that will be as effective as those available commercially.

If you are not given criteria for the solution to the problem (criteria are often given in technological problem solving), you can establish your own by asking some basic questions about the situation and the function of the device.

In this case, you are asked to design and produce a chemical pH indicator to meet the following criteria:

- Must be able to measure pH to at least the nearest 0.5 on the pH scale.
- Must be safe enough to pose no health hazard if spilled on the skin or ingested.
- Must have a shelf life of at least one month.
- Must be at least as economical as a comparable commercial product.
- Must be produced from readily available materials.

**Identifying possible solutions**

**Design 1: Poison Primrose Flower Extract**
Made by mixing dried and ground poison primrose flower petals, boiling the resulting powder in isopropyl alcohol, and filtering the resulting mixture to isolate the extract.

**Design 2: Red Cabbage Extract**
Made by mixing chopped up red cabbage with water in a blender and straining the juice (extract) off from the resulting mush.

**Planning**

**People:** The human resources required to solve this problem include you and your partner.
**Information:** You already understand the concepts of acidity and basicity. You will need to understand fully the pH scale. You may also need to find out about naturally occurring substances that react with acids or bases to produce different (e.g., visible) effects.
**Materials:** Within the limitations imposed by your proposed solution, cost, availability, safety, and time, you can use whatever materials you deem necessary.
**Tools:** Your design should not require any specialized tools or machines that are not immediately available.
**Energy:** The solution to this problem should not require any external source of energy.
**Capital:** The dollar cost must be low. Your solution must cost less to build than it would to buy a comparable commercial product.
**Time:** Because of the time limit on the scientific investigation, there is an even shorter time limit on the production of the indicator. You should be able to produce your indicator within 60 min. (This does not include designing and testing.)

The solution will be evaluated on how well it meets the design criteria established earlier.

**In this phase, you will construct and test your prototype using systematic trial and error. Try to manipulate only one variable at a time. Use failures to inform the decisions you make before your next trial. You may also complete a cost–benefit analysis on the prototype**

**To help you decide on the best solution, you can rate each potential solution on each of the design criteria using a five-point rating scale, with 1 being poor, 2 fair, 3 good, 4 very good, and 5 excellent. You can then compare your proposed solutions by totalling the scores.**

**Once you have made the choice among the possible solutions, you need to produce and test a prototype. While making the prototype you may need to experiment with the characteristics of different components. A model, on a smaller scale, might help you decide whether the product will be functional. The test of your prototype should answer three basic questions:**

- **Does the prototype solve the problem?**
- **Does it satisfy the design criteria?**
- **Are there any unanticipated problems with the design?**

**If these questions cannot be answered satisfactorily, you may have to modify the design or select another potential solution.**

## Constructing/testing solutions

**Table 1** illustrates the rating for two different designs. Note that although Design 1 came out with the highest rating, there is one factor (safety) that suggests that we should go with Design 2. This is what is referred to as a tradeoff. By reviewing or evaluating product and processes, we may be able to modify Design 2 to optimize its performance on the other criteria.

**Table 1:** Design Analysis

| Criterion | Design 1 | Design 2 |
|---|---|---|
| accuracy | 5 | 3 |
| safety | 3 | 5 |
| shelf life | 3 | 4 |
| economy | 4 | 4 |
| materials | 5 | 3 |
| **Total score** | **20** | **19** |

**In presenting your solution, you will communicate your solution, identify potential applications, and put your solution to use.**

**Once the prototype has been produced and tested, the best presentation of the solution is a demonstration of its use—a test under actual conditions. This demonstration can also serve as a further test of the design. Any feedback should be considered for future redesign. Remember that no solution should be considered the absolute final solution.**

## Presenting the preferred solution

The chosen design was presented to the chemistry class. A set of 12 test tubes was set up. Each tube contained a colourless solution of known pH, ranging from pH 1 to pH 14. Ten drops of red cabbage extract was added to each of the tubes. Students observed the colour changes and rated the results using a rating scale similar to the one used in the product testing stages. Students were given a list of the criteria used in the design and production stages, and were asked to provide comments regarding the indicator's performance.

**The technological problem-solving process is cyclical. At this stage, evaluating your solution and the process you used to arrive at your solution may lead to a revision of the solution.**

**Evaluation is not restricted to the final step, however, it is important to evaluate the final product using the criteria established earlier, and to evaluate the processes used while arriving at the solution. Consider the following questions:**

- **To what degree does the final product meet the design criteria?**
- **Did you have to make any compromises in the design? If so, are there ways to minimize the effects of the compromises?**
- **Did you exceed any of the resource parameters?**
- **Are there other possible solutions that deserve future consideration?**
- **How did your group work as a team?**

## Evaluating the solution and process

Our chosen product, red cabbage extract, meets most of the established criteria. Feedback from the chemistry class demonstration was positive. Unfortunately, the indicator does not change colour in the intervals pH 3 to 4 and pH 9 to 10, which limits how it can be used.

Kept in the refrigerator, red cabbage extract is still acting as a good pH indicator one month after it was prepared. Red cabbage is readily available. Its extract is safe for all uses and cheap to prepare.

In general, our group worked well as a team. However, some individuals pitched in a little more than others, especially in areas where they felt they they were more skilled. We have agreed that in future projects, every member of the team will work on something that is new to them, which will give each of us a chance to learn, and everyone will do their fair share in the final cleanup.