Design and Discovery

A TRANSITION YEAR MODULE

TEACHER GUIDE

Intel Ireland Public Affairs

PHOTO: DONAL MURPHY

PHOTO: JONATHAN HUNT

PHOTO: DAVID O'NEILL

PHOTO: ALINE GILMORE

Why?

Design and Discovery

"The best way to predict the future is to create it"

- Alan Kay

Why Teach Design and Engineering?

Participating in the design process provides students with the experience to understand how much of the world around them is created. Engaging in real design and engineering gives students an opportunity to look more critically at the designed world and tap into their own capacity to create change. It strengthens skills in problem-solving, creativity, risk-taking, and decision-making. The skills and knowledge developed have wide applicability across a variety of curriculum areas as well as in everyday life.

The *Design and Discovery* course is intended to serve as a 'stand alone' Transition Year module, and is suitable for all students. It does not require students to have a prior knowledge of science, or a high level of ability in mathematics. It is very much a hands-on, practical course intended to capture the interests of students, and give them insights into the processes that underlie problem solving, designing and making. The overall aims of the course fit with those in the Department of Education's statement of Transition Year Guidelines:

1. Education for maturity with the emphasis on personal development including social awareness and increased social competence.
2. The promotion of general, technical and academic skills with an emphasis on interdisciplinary and self-directed learning.
3. Education through experience of adult and working life as a basis for personal development and maturity.

In addition to the more general skills need to tackle problems, the course helps students develop their understanding of important ideas in science; especially those of energy changes, basic electricity, forces, motion, and properties of materials. The scientific concepts are introduced in context and designed to show how they can be used in practice.

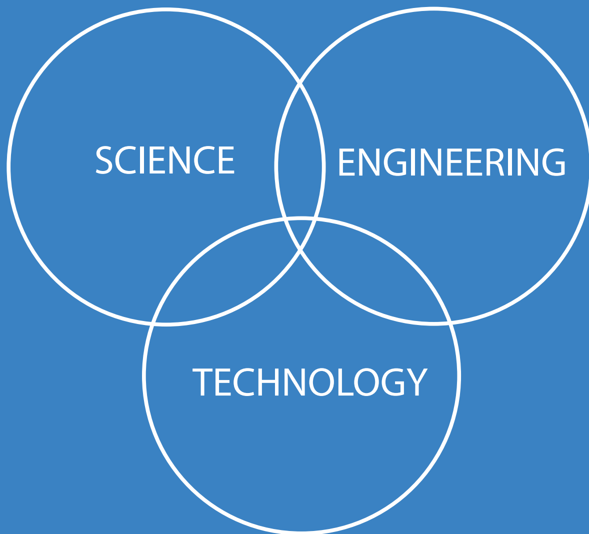
The course also fits the view of technology taken in the Junior Certificate Technology course: "Education in and through technology involves appropriate resources, suitable tasks, and the interplay between the two."

Design and Discovery Connects Science and Engineering

The *Design and Discovery Program* provides an environment where science concepts and skills are applied in ways that make them meaningful to students. The design and engineering process reinforces skills such as problem-solving, making and using models, collecting and interpreting data, inferring, formulating questions, and predicting-all skills shared between science and engineering. This is a unique opportunity for students to identify and design solutions to problems significant in their own lives.

The Massachusetts Science and Technology/Engineering Curriculum Framework (2001) describes the relationship between science, technology, and engineering this way:

"Science tries to understand the natural world. Based on the knowledge that scientists develop, the goal of engineering is to solve practical problems through the development or use of technologies."



"Science seeks to understand the natural world, and often needs new tools to help discover the answers."

"Technologies (products and processes) are the result of engineered designs. They are created by technicians to solve societal needs and wants."

"Engineers use new scientific discoveries to design products and processes that meet society's needs."

The Design and Discovery Approach: Hands-on Inquiry and Experimentation

Scientific inquiry and experimentation should not be taught or tested as separate, stand-alone skills. Rather, opportunities for inquiry and experimentation should arise within a well-planned curriculum. *Design and Discovery* promotes inquiry-based learning. Inquiry is an approach to learning that involves exploring the world, asking questions, making discoveries, and gaining new understandings. The inquiry process is driven by one's curiosity, interest, or passion to understand and solve a problem. In *Design and Discovery*, the inquiry process begins when students examine everyday objects and consider ways that they could be improved. Inquiry skills evolve throughout the sessions as students explore the world around them, identify a problem that interests them and through test and trials, develop ideas to solve the problem.

"In helping students learn, what is known should never be separated from how it is known."

- MA Science, Technology/Engineering Standards, 2001

Table of Contents

intel Education

Thinking Creatively about Problems and Solutions

Making, Modelling and Materializing

Prototyping and Final Presentations

TEACHER NOTES

Education

Introduction

Design and Discovery Introduction

This introductory course to engineering is aimed at transition year students. It is hoped that the course will get more young students interested in engineering through a hands-on design and interactive learning experience. The module offers an approachable and personally meaningful introduction to engineering through design.

The module focuses on some basic design and engineering concepts in which students follow a design process, used by professionals, that culminates in building prototypes of their ideas. The module encourages a hands-on, inquiry-based experience by encouraging students to identify and design creative solutions to everyday problems in the world of design and engineering.

Aims

- To develop students' understanding of the role of engineering and design in producing effective solutions to real world problems.
- To provide students with a background in electrical and mechanical engineering principles.
- To introduce students to the decision-making process of material selection in design based on material properties and economics.
- To improve the students problem-solving, analytical, and inquiry skills.
- To develop students' skills using hand tools to construct a prototype of an engineering design.
- To foster students' skills in independent learning, communication and teamwork.
- To develop students' ability to become experts and share their expertise.
- To allow students to make informed choices about Leaving Certificate subjects.
- To raise students' awareness of the many and varied career opportunities in engineering in Ireland today.

Objectives

At the end of the module the student will:

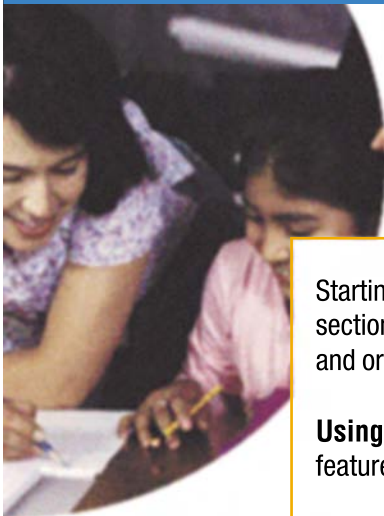
- Be able to recognise design opportunities in their everyday lives.
- Be familiar with a 10 step design process used by engineers.
- Understand the principles of simple mechanics, be able to identify different mechanical components and outline the function of those components.
- Be able to build a simple mechanical toy.
- Understand the principles of simple electronics, be able to identify different components and outline the function of those components.

intel Education

Design and Discovery Curriculum Introduction (continued)

- Be able to build simple electronic circuits and be aware of the practical applications of these circuits.
- Understand the economics of material selection and differentiate materials based on their properties.
- Understand the concept of systems, components and parts.
- Demonstrate methods of representing design solutions through sketching and orthographic drawing.
- Be capable of turning their ideas into reality by researching, modelling and prototyping.
- Have a completed project ready for showcasing at TY Open Day at which they present a design solution and communicate engineering and design expertise.

Implementation



Design and Discovery Implementation

Implementation

Using the Module
- Module Structure
- Scheduling
- Field Trips
- Supply Shopping List

Participating in Fairs
- YSTE
- Intel ISEF
- Hosting a Fair

Starting a new program may seem like a daunting task, but the **Implementation** section will help answer your questions and provide the background needed to plan and organize *Design and Discovery* as part of your school's transition year programme.

Using the Module presents information on the structure, processes, and major features of each of the 13 sessions in the curriculum.

Module Structure describes the common elements of each session and suggests strategies for grouping students during design investigations. It also explains what is meant by a Design Notebook, its importance and what it should contain

Scheduling outlines the timing of the sessions

Field Trips assists with all logistics in arranging meaningful field trips that integrate with the curriculum.

Supply Shopping List is a handy guide to all materials that need to be gathered, purchased, or borrowed for all sessions.

The *Design and Discovery* website contains lots of resources and supplemental materials including photographs and videos of projects and activities. This website may be found on http:www.skoool.ie. Click on Teachers tab. Select Design and Discovery.

intel Education

Using the Module

Module Structure

The *Design and Discovery* module engages students actively in the development of a personal design and engineering project through a sequence of 13 extended lab sessions that include investigative tasks, readings, discussions, and record keeping.

Each session typically begins with a warm-up discussion followed by hands-on activities or explorations done in small groups. Each activity includes a student worksheet that helps students work independently through activities. The student worksheet can be used to document ideas and results but students should be encouraged to capture all of their ideas and results in their design notebook. Activities may be supplemented with brief background readings or further research at Web sites.

Sessions can include "Homework" activities that are completed at home with the involvement and input of family members. All sessions involve reflection and record keeping in design notebooks that the students maintain throughout their projects.

Design Notebooks

The design notebook is a diary of progress of an idea. It is a place to record ideas, inspirations, discoveries, sketches, and notes. It is very important for students planning to participate in a science fair such as the Young Scientist & Technology Exhibition or who are interested in applying for a patent.

Design Notebook Guidelines

- Date and sign each page.
- Number each page.
- Never remove pages.
- Do not erase.
- Include explanation notes with any sketches or diagrams.
- Keep accurate and detailed notes.
- Be consistent and thorough.

Video Recordings

Capturing students' thoughts on video can serve as a powerful tool for reflection. Set up a video camera on a tripod at the end of each session and ask a few students to talk about their experiences and their projects. This can be organized with questions, prompts, or left open for students to just talk. It can be done in pairs or individually, although students will probably feel more comfortable in front of a video camera with a friend.

intel Education

Module Structure (continued)

Suggested Prompts

- Explain what you worked on today and how it helped further your project.
- Explain how you are feeling about your experience in Design and Discovery.
- Explain what your goals are for your project and how you plan to meet them.
- Explain what has been most helpful so far in developing your project.

The video can be shared with the students throughout Design and Discovery as a way to discuss and reflect upon the design process. It may be shared with parents so that they can see what their child is thinking and doing in Design and Discovery. It can also be edited and made into a short video piece to be shown at the final presentation.

Grouping

Session descriptions indicate when it is preferable to have students work in small groups or in pairs. Otherwise, the module is flexible for students to work as the teacher wishes. In sessions where students are grouped, it is recommended that students rotate through different groups or pairings to encourage students to work with different people.

It is also up to the teacher to decide how the students will work on their design projects. It is suggested that they work individually or in pairs. If they work in pairs, they should be able to get together outside of class time to work.

Using the Module

Scheduling

The *Design and Discovery* transition year module covers approximately 13 x 120 minutes of contact time with students.

The first class period should be spent introducing *Design and Discovery* to students.

A schedule would divide sessions over two to three school periods depending on the length of a period. With two to three periods per week devoted to *Design and Discovery* sessions, the program could be completed in a term.

Using the Module

Field Trips

Local field trips are a wonderful way to expose students to the real world of design and engineering Try to relate the field trip to components of the design process. Field trips should be designed to give students a unique opportunity to experience engineering in the real world. Field trips need not be expensive. The designed world is all around us, so even something as simple as a structured trip to the supermarket can be an effective field trip. Look for opportunities to show students engineering solutions at work. This can be as complex as an automated packaging plant or as simple as the water slide at the local pool.

Making Contact

To schedule a field trip, start with your personal connections. Most companies will allow behind-the-scenes tours, especially if an employee has an interest in it. Ask parents about their workplaces and jobs. Next, contact local branches of professional engineering organizations, such as the IEI (the Institute of Engineers of Ireland http://www.iei.ie/Home/index.asp. Members of the IEI work in the engineering field and may be interested in helping some aspiring engineers.

Before the Field Trip

To get the most out of a field trip experience, it is important to be prepared. Familiarise the host organisation with the module and establish a clear plan. Have goals and expectations clearly discussed up front. Students can come up with questions or can be provided with a scavenger hunt. Students should be prepared to draw sketches, take pictures, and take notes to record their observations. Before going, pose the following questions: *What are we trying to find, discover, or understand today? How will you record what you find?*

Field Trips (continued)

During the Field Trip
Encourage students to look for solutions that they have seen designed. Be sure to debrief during the field trip. Discussion questions might include: *What did you find that others should see? How did you figure out how a design solved a problem? Are there additional problems you see that still exist?* Keep asking targeting questions that connect to the goals of the field trip. Tell them to look for things like specially placed lighting, signage, ways of containing or displaying materials, items that do one specific job, and features of the place they are visiting that have been designed to solve a problem. Tell them to notice informational displays and interpretive boards. Discuss: *How are materials presented? How is important information conveyed? How are pictures used? Drawings? Models?*

Allow time for sketches and picture taking, with the goals in mind. Ask that students share these pictures when they return as ways of reminding themselves and others what they saw that was valuable. They should also take advantage of any contacts they meet who can help them with their design projects.

After the Field Trip
Debrief the field trip by discussing what students got out of it and how the experience will help them with their projects. Have them share observations, sketches, and photos. Don't forget to send thank-you notes!

Field Trip Alternatives
If a field trip is not possible due to time or distance, consider inviting a local engineer, designer, or inventor to present to the group. Ask for an interactive presentation with a hands-on activity for the students.

Suggested Field Trips and Experts (By module session)

Jump into the Designed World (session 1)
- A walk around the school to identify problems, needs, and opportunities

Engineering Fundamentals
- Experts: electrical engineer, mechanical engineer

The 3 R' of Problem Identification (session 6)
- A visit to a place, such as a shopping centre, to conduct interviews and get feedback on their ideas
- Experts: materials engineer

Field Trips (continued)

Making, Modeling, and Materializing

- A field trip to a bicycle repair shop
- A visit to the modeling shop of a design firm
- A trip to a hardware or home improvement store to look at parts and components
- Experts: product designer, shop manager, handyperson

Prototyping and Final Presentations

- A visit to a design firm to see prototypes
- A place to conduct user testing on prototypes
- Expert: product designer
- Guest speakers: engineer, product designer

Other Field Trip Ideas

- Manufacturing or packaging plant
- Supermarket
- Train station or rail yard
- Commercial farm with equipment
- Post office
- Water park (slides, tubes, fountains, etc.)
- Auto repair shop
- Machine shop
- Distribution warehouse
- Commercial bakery
- City waterworks or sewage treatment plant
- Power generation dam
- Bridges
- Locks
- Shipyards and docks
- Shopping malls (with escalators, people movers, etc.)
- Light rail, trolley or transit system
- Construction site
- Rock quarry
- Military base
- Ship (merchant marine, military, cruise)
- Army Corps of Engineers
- City, county, or state engineering departments

Using the Module

Supply Shopping List

Below is a supply list with materials compiled by the six sections of the curriculum. When organizing the materials for each session and activity, you will need to refer to the supplies listed in each session and activity as well as the Supplies page. Of course, many of these materials can be supplied by the students, mentors, and other volunteer donations.

Prices listed below are approximations. Most of the material can be found at any hardware or stationary shop. Electrical products can be found at most good electrical shops or can be ordered on line from Maplin Electronics (www.maplin.co.uk). Specially commissioned Design and Discovery electronics kits are available from William Cooney, Cooney Electronics, 15 Windsor Avenue, Dublin 3. Phone 01 8334703.

Understanding the Design Process

Session	Item	Quantity	Cost
1B	Straight pins	40	€2
1B	Safety pins	40	€2
1B	T pins	40	€2
1B	Variety of paper clips	40	€2
1B	4 different types of wire	4 metres each of 4 different types of wire	€20
1B, 4A, 5C	Wire cutters/strippers	1 for each pair of students	€10
1B, 6C	Needle-nose pliers	Several pairs of both	€10
1B	Scratch paper to test solutions	Stack of paper	€2
1B	Rulers	A few rulers	€1
1B	Embellishment supplies such as beads, buttons, etc.	Enough for each student	€5
2A	Potato peelers in multiple styles	A few samples per group	€2
2B	Fruit (potato) mashers	1 per pair of students	€2

Supply Shopping List (continued)

Engineering Fundamentals

Session	**Item**	**Quantity**	**Cost (**Maplin part no.)
4/5	Breadboard	1	€6.15 (AG10L)
	9V battery (PP3)	1	€4.65 (AR46A)
	clip for battery	1	€0.36 (NE19V)
	4093B CMOS chip	2	€0.60 (QW53H)
	2003A Darlington Driver chip	2	€0.60 (AD93B)
	Small 3V lamps	2	€0.60 (L81AH)
	Lamp holders	2	€0.48 (VW65V)
	Resistors, 1K, 10K, 22k, 47k	2 of each	€0.011 each in lots of 25 (G1K, G10K, G22K, G47K)
	Capacitors, 10mF, 22mF, 47mF, 100mF	2 of each	€0.05 (VH22Y, VH26D, VH32K, VH37S)
	LEDs, red, green	2 of each	€0.226 each in lots of 25 (J64U, CJ65V)
	Motor	1	€4.79 each (HA83E)
	Reed switch and magnet (sold as pair)	1	€2.44 (YW47B)
	Push switch	1	€0.60 (FH59P0
	Micro switch	1	€1.83 (N96AQ)
	Buzzer	1	€1.36 (FL39N0
	Selection of wires - best purchased as a kit that should supply enough for all groups.	8 (say)	€12.24 (FS65V)
6A	Film canister with lid, with holes drilled in both ends - Plastic tablet containers work just as well and can be obtained from your local pharmacist	1 per student	€0.10

Supply Shopping List (continued)

Session	Item	Quantity	Cost
6A	Rubber bands (#30 or #31) (dimensions 6.5 cm x 3 mm x 0.7 mm, #31 is slightly heavier)	1 per student	€0.10
6A	Washers 1.25 cm or 2 cm outside diameter)	2 per student	€0.20
6A, 6B	Thick drinking straws	1 per student	€0.10
6B	Small wooden dowels (Bamboo skewers will work.)	Optional	€1
6B	Tools that use moving parts: eggbeaters, hand drills, winged corkscrews, flour sifters, ice cream scoopers, nut grinders, and manual can openers	A variety	€20
6B	Milk carton	1 per student	€1
6B	3 pieces 16-gauge steel wire; one 20 cm length, two 7.5 cm lengths	3 per student	€3
6B	Electrical tape or long bead (for crank handle)	For all students	€2
6B	Miscellaneous gears, belts and wheels, wire, art supplies, and other materials of choice	Enough for each student	€10
6C	Lego Technic* (Item #8735) (toy construction set)	1 set	€50
7	Requires use of computer		

* can be ordered on line at www.shop.lego.com

Supply Shopping List (continued)

Thinking Creatively About Problems and Solutions

Session	Item	Quantity	Cost and Purchase Information
8/9	Require use of computer with internet access		

Making, Modelling and Materializing

Session	Item	Quantity	Cost and Purchase Information
10D, 11A *(continued)*	Structural materials: • Foam (Styrofoam* in sheets and several shapes, including foam tubes for pipe insulation) • Foam core board • Balsa wood (sheets and pre-cut strips from craft supply stores) • Modeling clay • Aluminum foil • Pipe cleaners and plastic straws • Cardboard (tubes, boxes of all sizes, flat pieces) • Paper (including poster board or card stock weights) • Lego* set • Dowels, bamboo skewers • Wheels		

Supply Shopping List (continued)

Session	Item	Quantity	Cost and Purchase Information
10D, 11A *(continued)*	Optional structural materials: Recyclable materials: • Wine corks • Aluminum soda cans • Bubble wrap • Packaging peanuts • Twist ties Sample items for students to acquire and use in large constructions: • PVC pipe and connectors • Lumber (plywood and 2x4s) of different sizes	Enough for each student to have a choice of materials	
10D, 11A	Parts and materials to connect things: • String • Wire • Rubber bands • Rubber tubing • Tape (duct, masking, packaging, and electrical) • Glues (epoxy, superglue, glue sticks, glues for hot glue gun, and rubber cement)	Enough for each student to have a choice of materials	

Supply Shopping List (continued)

Session	Item	Quantity	Cost and Purchase Information
10D, 11A *(continued)*	• Hinges • Nuts and bolts • Washers • Assorted screws • Nails • Thumbtacks		
10D, 11A	Tools: several sets of each: • Pliers • Saw • Hammer • Screwdriver • Hot glue gun • Tin snips	Several sets of each	 €5 €12 €12 €5 €10

Prototyping

Session	Item	Quantity	Cost
12C, 13A	• Wood • Foam • Plexiglass • Fiberglass • Metal • Canvas fabric • Bubble packing • Cotton balls • Tubing • Sandpaper • Sponges • Steel wool pads	Enough for each student	Have students bring in.

Supply Shopping List (continued)

Prototyping

Session	Item	Quantity	Cost
12C, 13A *(continued)*	• String or twine • Glue • Masking tape • Duct tape		€1 €1 €2 €2
12B	Spreadsheet software program and computers		

Final Presentations

Session	Item	Quantity	Cost
13D	• Scissors • Colored paper • Rubber cement • Markers • Scrapbooking supplies • Glue sticks • Other art materials	Enough for each student	

Participating in Fairs

Showcasing Student Learning

Participating in Fairs provides information on opportunities for students to share their hard work by showcasing their projects and competing in engineering competitions.

The Young Scientist and Technology Exhibition is Irelands national science and technology fair which has been running for over 40 years. It provides an opportunity for the country's best young scientists and inventors to come together to share ideas.

The exhibition takes place every January in the RDS, Dublin. Winners of the physical science section go on to participate in the Intel International Science and Engineering Fair (ISEF) which takes place in Portland, Oregon every May.

Any student aged between 12 and 18 years on 31st October, from any secondary school throughout Ireland both North and South, is eligible to submit a project.

Students can choose to enter a project in one of the following four categories.

1. Biological and Ecological Sciences
2. Chemical, Physical and Mathematical Sciences
3. Social and Behavioural Sciences
4. Technology

For a project to be accepted into the technology category the core of the project must be the application of technology in new or improved products, enhanced efficiencies, new innovations or better ways to do things. The category could include things related to the Internet, communications, electronic systems, robotics, control technology, applications of technology, biotechnology, innovative developments to existing problems, computing and automation.

The Chemical, Physical and Mathematical Sciences category covers projects on chemistry, physics, mathematics, engineering, computer programming, electronics and encryption as well as earth and space sciences such as meteorology, geophysics and astronomy.

For more information on the Young Scientist and Technology Exhibition and how to enter please visit http://www.btyoungscientist.ie

Participating in Fairs

Intel ISEF

The Intel International Science and Engineering Fair (ISEF) (www.intel.com/education/isef/) is the world's largest pre-college science competition. It provides an opportunity for the world's best young scientists and inventors to come together to share ideas, showcase cutting-edge science projects, and compete more than US$3 million in awards and scholarships. Each year, 10 to 15 percent of finalists file for patents on their projects.

Overview

The Intel ISEF is the world's only international science fair representing all life sciences for students. Every year, more than one million students in grades 9-12 compete in regional science fairs and nearly 500 Intel ISEF-affiliated fairs held around the world. Then, at Intel ISEF, more than 1,200 students from 40-plus countries win the chance to compete for the scholarships and prizes in 14 scientific categories and a team project category.

The Intel ISEF has been coordinated for 53 years by Science Service, one of the most respected nonprofit organizations advancing the cause of science. As title sponsor, Intel Corporation has committed millions of dollars to developing and promoting this competition. In addition, each year a volunteer committee representing the host city raises funds to sponsor events throughout the fair.

Intel's Sponsorship

Intel became the first title sponsor for the Intel ISEF in 1997 as a way to recognize and reward excellence in science from the world's best young scientists, and to encourage more young people to explore science and technology in their higher education and career choices.

Since assuming the sponsorship, Intel has focused on increasing international participation and adding new awards such as Young Scientists Scholarships, Achievement Awards, Best of Category, and awards to teachers and fair directors. Intel's sponsorship of the Intel ISEF is part of the Intel® Innovation in Education initiative to prepare today's teachers and students for tomorrow's demands.

Participating in Fairs

Hosting a Fair

Many schools Transition year students generally have an awards and achievements open evening which would be a suitable showcase for students designs.

This culminating event should recognise the students' hard work and celebrate their accomplishments. Students can share their engineering expertise with others, practice presenting projects to an audience, get feedback on their projects, display boards, prototypes and presentations.

Notes:

Overview and Planner

Design and Discovery Overview and Planner

Design and Discovery is a comprehensive inquiry-based course for transition year students. The course introduces engineering through design and it is hoped that having completed the course the student will appreciate the prevalence of engineering and design in the world around them. The course is organised into 13 sessions. Each session is intended to be of two hours duration (three forty-minute periods). It is preferable if two of these periods are available as a double period in order to facilitate the practical work. The teaching units of the module could then be covered in a thirteen-week period.

Each activity includes a teacher's instruction page and a student worksheet with directions for students. However, in addition to completing the worksheets students are encouraged to record their work in their design notebook. Supplies are listed for each session. Many activities also include a student reading. The readings often provide real-world examples of professionals working in the design and engineering world.

All of the Student Worksheets and Student Readings, which are in the Teacher Guide, have also been duplicated in the Student Booklet.

A Design and Discovery Planner is printed after the list of sessions. A copy is also included in the Student Booklet. At the start of the module students should be made familiar with the planner and encouraged to take ownership of the module and keep track of their own progress. Periodically, teachers should refer to the planner, thus ensuring that the students complete their projects on time.

Understanding the Design Process

Students are introduced to the designed world and then practise the design process that is revisited throughout the module.

Session 1: Jump Into The Designed World I
Students re-think and re-engineer everyday objects. These hands-on activities reinforce a ten-step design process that is used many times throughout the Design and Discovery module.

Session 2: Jump Into The Designed World II
Students learn that design opportunities are everywhere. This session builds their ability to analyse existing objects for improvements and helps students identify suitable problems to solve with design and engineering.

Design and Discovery Overview and Planner (continued)

Session 3: Material Science
From spacecraft to ballpoint pens, materials make the difference in successful performance of a product. Students learn about four different classes of materials and test them to understand their properties. They apply selection criteria to determine the best materials for different applications, while learning to consider cost and environmental impact when choosing materials.

Engineering Fundamentals

These sessions provide background in electrical and mechanical principles that students may need to incorporate in their designs.

Session 4: Electronic Engineering I
Circuits are the building blocks of all electrical appliances. In this session, students explore simple circuitry with bulbs, batteries, wires, and breadboards.

Session 5: Electronic Engineering II
Students continue to learn about simple circuitry. They use reed switches, LEDs and motors and begin to think about their application in the world around them.

Session 6: Making Machines and Observing Functionality
Students study mechanics and motion. They build simple mechanical devices such as a rolling toy and a crankshaft. This session also introduces students to motors and explains how motors can be used to produce motion.

Session 7: Robotics
This session will expand the students' knowledge of the world of robotics. Students will identify many of the different types of robot in general use and will carry out activities that illustrates some of the issues that arise in the programming of these devices.

Thinking Creatively about Problems and Solutions

In these sessions, students identify interesting problems and develop ideas for solutions.

Session 8: The 3 R's of Problem Identification
The 3 R's of problem identification invites students to revisit, refine, and research design opportunities for a project of their own. Using a variety of techniques, students narrow down their list of design opportunities.

Design and Discovery Overview and Planner (continued)

Session 9: A Solution Taking Shape
Preparing a design brief helps students to focus their understanding of a problem and propose a solution. Students delve deeper into their proposed design solution as they research patents for similar ideas and consider the necessary parts to get from "think" to "thing."

Making, Modelling and Materializing

Students turn their thinking into things and begin several cycles of building trials and testing their ideas.

Session 10: Project Analysis and Planning for Models
Students begin this session by reviewing their solution before proceeding to the next steps. They make sketches of their design in their design notebooks and list the materials that they need to make their model.

Session 11: Making It! Models, Trials, and Tests
Let the construction begin! Pieces, parts, and connections become trials and models of a system, a component, or the product itself.

Prototyping and Final Presentations

In these sessions, students refine their project into a working prototype and learn how to display and present their projects.

Session 12: Prototype Practicalities
Projects are taken to the next level as students plan how to develop their working prototypes. They consider the product specifications, materials and budget. Students begin to construct their prototype.

Session 13: Prototype Review and Presentation
This work session gives students more time to work on their prototypes. They may need to make several prototypes as they conduct trials and tests of the product. Conducting user testing allows students to try out their products, get feedback, evaluate the feedback, and plan their revisions. In this final session students begin to prepare for the end of year exhibition. Preparation involves planning the event and designing a display. Students practise their presentations and receive feedback from their peers. Following the event, they reflect on their *Design and Discovery* experience.

Overview

Planner

Session No. (3x40 mins)	Topic	Notes and Comments	Date Started	Date Completed
1	Jump Into The Designed World I			
2	Jump Into The Designed World II			
3	Material Science			
4	Electronic Engineering I			
5	Electronic Engineering II			
6	Making Machines and Observing Functionality			
7	Robotics			
8	The 3 R's Of Problem Identification	* __ weeks to exhibition		
9	A Solution Taking Shape	* __ weeks to exhibition		
10	Project Analysis and Planning for Models	* __ weeks to exhibition		
11	Making It! Models, Trials and Tests	* __ weeks to exhibition		
12	Prototype Practicalities	* __ weeks to exhibition		
13	Prototype Review and Presentation	* __ weeks to exhibition		

Dates to Remember

Transition Year Evening/Science Fair

Date ____________

Young Scientist & Technology Exhibition (www.btyoungscientist.ie)

Date ____________

Pre-Survey

Design and Discovery Pre-Survey

Please answer the questions below honestly. There are no right or wrong answers. Your survey will be kept confidential. Select the number indicating your level of agreement with the statements. Thank you for sharing your thoughts.

	Disagree	Disagree a little	Agree a little	Agree
1. I like taking things apart and putting them back together again.	1	2	3	4
2. I am interested in my maths class.	1	2	3	4
3. I am good at designing things.	1	2	3	4
4 I like to know how things work.	1	2	3	4
5. I enjoy doing projects in school that involve maths and science.	1	2	3	4
6. I often think about what I want to do after I graduate from school.	1	2	3	4
7. I know what an engineer does.	1	2	3	4
8. I am good at solving problems.	1	2	3	4
9. I would like a career that requires a maths or science background.	1	2	3	4
10. I can explain my ideas to someone else so they can understand them.	1	2	3	4
11. I would like a career that involves designing things.	1	2	3	4
12. It is important for me to be good at science.	1	2	3	4
13. Creative thinking is one of my strengths.	1	2	3	4
14. I try to think of different ways to solve a problem before deciding on a solution.	1	2	3	4
15. I like to find out things on my own.	1	2	3	4
16. I like working with a team to create things or solve problems.	1	2	3	4
17. I could be a successful engineer.	1	2	3	4
18. I try to solve problems first before asking for help.	1	2	3	4
19. I consider myself mechanically inclined.	1	2	3	4
20. I am interested in pursuing a career in engineering.	1	2	3	4

Design and Discovery Pre-Survey (continued)

21. Describe what you think an engineer does at work. What kinds of skills are needed to become an engineer?

____

____

____

22. Name some things that have been created by an engineer?

____

____

23. What type of career are you interested in?

____

24. The courses/skills that you most need for your career choice are (check all that apply):

art ☐ computers ☐ English ☐ maths ☐ science ☐ writing ☐

other (what? ______________________________)

26. What types of things do you think you will learn while participating in this program?

____

____

First two letters of your:

___ ___ first name*

___ ___ last name*

___ / ___ / ___ Date of birth*

Thank you for your time and thoughts.

**This information will allow us to follow your responses over time.*
We will summarize all data, however, and no one will be identified.

Understanding the Design Process

Session 1

Jump into the Designed World I

In This Session:

A Survey and Introduction (40 mins)

B Build a Better Paper Clip (60 mins)
- Student Reading
- Student Worksheet

C The Design Process (20 mins + H/W)
- Student Reading
- Student Discussion

The designed world orients students to a design process that guides the work of engineers and designers. Hands-on activities build understanding of the role of engineering and design in producing effective solutions to real world problems.

In *1B: Build a Better Paper Clip* students carefully examine the form and function of standard paper clips. Given a set of wires and tools, they are challenged to design a new paper clip that meets predetermined requirements. This design challenge provides a firsthand connection with a 10-step design process that is introduced in a group activity, *1C: The Design Process.* Students should be encouraged to bring home their work and continue as homework.

1C: The Design Process forms the foundation for work on students' own projects, and each step is revisited in greater depth in subsequent sessions. This session builds appreciation for the designed world around us and prepares students for finding a design and engineering project. Students develop skills by thinking creatively about designed things they use. They also learn to identify problems that lead to opportunities for new design solutions.

Supplies

- For each student: straight pins, safety pins, and a variety of different types of paper clips of varying sizes
- 4 metres each of 4 different types of wire cut into lengths of 30 cm for designing paper clips
- Several pairs of wire cutters and needle-nose pliers
- Stack of scratch paper to test solutions
- A few rulers
- Additional materials for embellishment, such as beads, buttons, superglue, etc

Intel Education

Jump Into Design

Key Concepts: Session 1

In Session 1, students are introduced to the concept of design and engineering as a *formal process* through a series of hands-on activities. They begin with redesigning a simple object - the paper clip - in order to develop a common reference point as they begin their experience with the design process. This experience with the design process builds an important foundation for the rest of the activities in *Design and Discovery* as the design process forms the basis of the curriculum.

Key Concepts

The Design Process: A systematic problem-solving strategy, with criteria and constraints, used to develop many possible solutions to solve a problem and to narrow down the possible solutions to one final choice.

The design process is a recognized set of generally defined steps designers and engineers use based on a problem-solving strategy that leads to product development. It begins with the identification of a problem through a series of exploratory and data-gathering stages, to a creation of a solution. Though the process is introduced as a series of sequential steps, it is important to understand that the process is not truly linear - it is much more like a design *cycle* since many of the steps are intended to be revisited as more information is gathered. Because this forms the core of the curriculum, adults working with students must be comfortable with the process and how it plays out in the subsequent activities. Students are introduced to the design process in 1C, Worsheet, The Design Process.

If you recall "the scientific method" you were introduced to in science classes, you will recognize the similarity of a sequenced set of steps, used as reference by professional scientists. There are natural and logical steps that facilitate the desired outcome. However, the scientific method and the design process are fundamentally different. While scientists propose a "solution" up front (the hypothesis) and then test it through experimentation to see if it is correct, designers identify the problem, define it as a design challenge, then brainstorm, research, gather data and test to identify *what the correct solution should be.* The "solution" is arrived at later as a result of the process of data gathering and experimentation. Both represent the formal process used by each profession from each field, though inquiry and experimentation are at the heart of both.

Session 1, Activity B

Build a Better Paper Clip

In This Session:

A Survey and Introduction (40 mins)

B Build a Better Paper Clip (60 mins)
- Student Reading
- Student Worksheet

C The Design Process (20 mins + H/W)
- Student Reading
- Student Discussion

Goal

Experience the design process by re-engineering an everyday object.

Outcome

Design and engineer a new paper clip that meets requirements.

Description

After careful observations of how different kinds of paper clips function and perform, students design a new paper clip that meets several requirements including a unique look. They construct them using a selection of materials and prepare drawings of the various designs. Each designer presents a new paper clip model.

Note About Wire

Wire needs to be flexible but have sufficient springiness to retain its shape after some bending. Recommended: Steel or copper wire, 14 or 18 gauge. Floral stem wire (18 gauge steel) is available in craft stores and floral shops.

Preparation

1. Read *1B Reading: The Perfect Paper Clip.*

Procedures

1. Briefly review the purpose and importance of keeping notes, sketches, and ideas in a design notebook. Point out the value of putting dates on notebook pages.
2. Refer to the worksheet with the design requirements, and allow time for students to read it thoroughly.
3. Describe the materials and tools for the design challenge and review requirements as needed.
4. Encourage students to experiment carefully with all the examples provided, exploring the ability of various materials to hold paper.
5. Remind students to make notes about their observations of different materials and paper clip designs in their design notebooks.

intel Education

1B: Build a Better Paper Clip (continued)

6. Move among the students and discuss their observations about the materials and the extent to which they bend and spring back, retaining the ability to "hold" materials.

7. Remind the students to draw quick sketches in their design notebooks of their ideas and note test results.

8. Monitor progress and allow 40 minutes for designing, engineering and testing.

9. The remaining 20 minutes should be spent evaluating the designs. Ask each student to briefly present their prototype.

10. Discuss whether or not the prototypes fit the given criteria.

Wrap Up

Each student presents a brief explanation and demonstration of his or her paper clip design.

Follow With

In the next activity, *1C: The Design Process,* students become familiar with the design process which they will use throughout the sessions.

The Perfect Paper Clip

Reading: Session 1, Activity B

Why in the world would you study a paper clip as you learn about engineering and design? Henry Petroski, a professor of civil engineering, has written many interesting books about design and engineering in everyday things. In his book, *Invention by Design,* he devotes a whole chapter to paper clips. He notes that the paper clip, although one of the simplest of objects, can provide many lessons about the nature of engineering.

We take paper clips for granted—it seems as if they've always been around. In fact, they've been in use only since around the time of the Industrial Revolution. Before that, paper was held together with straight pins. However, the straight pin was difficult to thread through more than a few sheets of paper because it left holes in the paper, and it bulked up piles of paper.

With the developments of the Industrial Revolution, however, volumes of paper increased as technology enabled business to expand nationally and internationally. The paper clip had a clear advantage over the straight pin in holding together a group of papers, and eliminated pricked fingers! The increase in technology associated with the Industrial Revolution also allowed paper clips to be produced in quantities that kept the cost per clip low.

Early versions of the paper clip had problems that later versions sought to remedy. The paper clip we know and love today, with its (almost) perfect design, did not start out that way. Earlier models got tangled together, slipped off too easily, had too much "springiness" or not enough…

As Henry Petroski notes, the paper clip we are familiar with works because:

"… its loops can be spread apart just enough to get it around some papers, and when released, can spring back to grab the papers and hold them. This springing action, more than its shape per se, is what makes the paper clip work. Springiness, and its limits, are also critical for paper clips to be made in the first place."

The most successful paper clip yet designed is the Gem* clip. The shape of the Gem clip was introduced in England in the late 19th century by a company known as Gem, Limited. The classic Gem has certain proportions that seem to be "just right."

Petroski quotes an architecture critic who had the Gem in mind when he wrote:

"Could there possibly be anything better than a paper clip to do the job that a paper clip does? The common paper clip is light, inexpensive, strong, easy to use, and quite good-looking. There is a neatness of line to it that could not violate the ethos of any purist. One could not really improve on the paper clip, and the innumerable attempts to try—such awkward, larger plastic clips in various colors, or paper clips with square instead of rounded ends—only underscore the quality of the real thing."

1B Reading: The Perfect Paper Clip (continued)

The Gem became to paper clips what Kleenex* is to facial tissue because of a patent issued to William Middlebrook, of Waterbury, Connecticut, in 1899. The unique aspect of Middlebrook's patent was that, although there were many inventors patenting all sorts of sizes and shapes of paper clips, Middlebrook was patenting the machine that would form the paper clip economically.

Petroski writes:

"The complexity of Middlebrook's machine is clear from his patent drawings, and it is apparent that he was engaged in serious mechanical engineering…The principles upon which the machine works, bending wire around pegs, are well suited to the Gem design and it to them. In short, Middlebrook's machine and the Gem were made for each other."

So the combination of a well-designed paper clip and a well-designed machine led to the success of the Gem clip today.

The architecture critic aside, many believe that even the Gem could use improvement: It goes on only one way; it doesn't just slip on; it doesn't always stay on; it tears the papers; it doesn't hold many papers well.

This is what makes engineering and inventing so challenging. All design involves conflicting objectives and thus compromise. The best designs will always be those that come up with the best compromise.

Of course, inventors will always look for ways to improve upon an object. They will continue to look for ways to make a better paper clip. Newer clips, for instance, may be plastic coated, or shaped like Gems, yet their proportions never seem to be quite right. One improvement to the paper clip has been the introduction of a turned-up lip on the end of the inner loop. This allows the paper clip to slide onto the papers without actually opening the clip. As mentioned above, design involves tradeoffs. This "improvement" adds to the bulk of bundled papers.

One key point to remember is that the laws of nature always bind invention, design, engineering, and manufacturing. Change in one area of design may lead to design weakness in another.

To inventors, the quest for the perfect paper clip remains elusive. Perhaps the simple paper clip isn't so simple a device after all!

Adapted from:

Petroski, Henry. *Invention by Design: How Engineers Get from Thought to Thing.* Cambridge, MA: Harvard University Press, 1996.

Build a Better Paper Clip

Worksheet: Session 1, Activity B

Exploration

Explore the paper clips and pins (two types of fasteners) that you have in front of you. Pins were used to fasten paper together before the invention of the paper clip. Pay close attention to your hands and fingers as you use each one to fasten together pieces of paper. What do you notice?

You might notice the action needed to separate the paper clip loops so it slips onto the papers; the way your fingers direct the clip onto the papers. Each of these actions is unconscious, and the ease with which the object is used indicates a successful design.

Explore the properties of the shape and the materials of each paper clip design. Observe the operation of each design, make notes about each, and apply what you learn to designing a unique, new paper clip. What is common about the way each shape works to do the job? What properties in the material (the metal) allow each to do the job of fastening paper together?

Design

You have wire, tools, and examples of paper clips. You must now design a prototype of a new paper clip that meets several design requirements listed below. Try out your ideas and make drawings of your designs. Choose one to engineer and test it. Be prepared to present your model.

Student Challenge

The owners of P&C Office Supplies are seeking new designs for paper clips. The company has come across hard times and believes a new paper clip design could revive their once thriving business. It is up to you to save their company. Use your imagination and creativity to invent a new paper clip design, the owners have come up with requirements for the design.

Requirements

- Your paper clip will be unique. It cannot look like any paper clip you have ever seen before, but may have features of other clips.
- It can be no bigger than 2 inches square.
- It must not be a hazard to small children.
- You may use other materials to enhance your design, but your main material must be wire.
- It must hold 10 pieces of paper together.
- You should use your design notebook to draw your various designs.

Session 1, Activity C

The Design Process

In This Session:

A Survey and Introduction (40 mins)

B Build a Better Paper Clip (60 mins)
- Student Reading
- Student Worksheet

C **The Design Process (20 mins + H/W)**
- Student Reading
- Student Discussion

Goal

Become familiar with the design process.

Outcome

The experience with designing paper clips is formalized into a design process that guides students throughout their design and engineering projects.

Description

A small group discussion of the paper clip design activity collects the students' experiences with the design process they experienced directly. The discussion moves to connecting their experience to a general design process outlined on 1C Worksheet: The Design Process. A short reading that clarifies the relationship among design, engineering, and scientific research wraps up the activity.

Supplies

White board and markers, or computer to display discussion points

Preparation

Black board and markers, or computer to display discussion points.

Procedures

Brief Discussion

1. Ask students to reflect on their experience with designing a new paper clip. You might prompt them to think about:
   - What gave them their ideas?
   - What stages or steps did they go through as their ideas took shape?
   - What helped them move their idea into a prototype?

2. Ask students to share their experience with their designs. Have each person share. Make quick notes on black board. Call attention to areas of common experiences.

intel Education

1C: The Design Process (continued)

Design Process Review

1. Look at the 1C Worksheet: The Design Process, and have students take turns reading each step out loud.

2. Discuss any connections between the students' experience and the design process as you go through each step.

3. Emphasize that the design process is iterative—that is, it goes through cycles or iterations as steps are revisited throughout the process.

Wrap Up
Ask participants to look around the room and discuss:

- What things in the room were designed?
- Which ones were engineered?
- What is the difference between design and engineering?
- What does the expression "form follows function" mean to you?
- What happens when function is forced to follow form? (In other words, when something is designed first and then someone figures out what to do with it.)
- Why is it important to have form follow function?

The Design Process

Worksheet: Session 1, Activity C

Getting From "Think" To "Thing"
We will be using a design process to guide the development of a project from your idea to the design of a prototype. The steps of the design process are iterative, or cyclical. That means that throughout the stages of designing a product, you will revisit many of these steps as you refine your ideas.

1. **Identify a design opportunity.**
   Notice that design opportunities are everywhere and often come from a need, problem, or improvement to an existing solution. The goal is to identify many design opportunities and then narrow them down later.

2. **Research the design opportunity.**
   Gather lots of information about the nature of the problem in order to narrow your choices down. Find out about user needs and similar products.

3. **Brainstorm possible solutions to the problem.**
   Try to come up with five to ten ideas for solving the problem or addressing the design opportunity. Brainstorming may involve the use of SCAMPER and other techniques.

4. **Write a design brief.**
   Define the problem clearly in a problem statement. Describe the user needs and a proposed solution. Draw a sketch of the solution.

5. **Research your solution.**
   Do a literature review and talk to experts to find similar solutions and other approaches.

6. **Refine your solution.**
   Analyze the solution for feasibility, safety, and implications of the idea. Consider materials and methods for constructing the project.

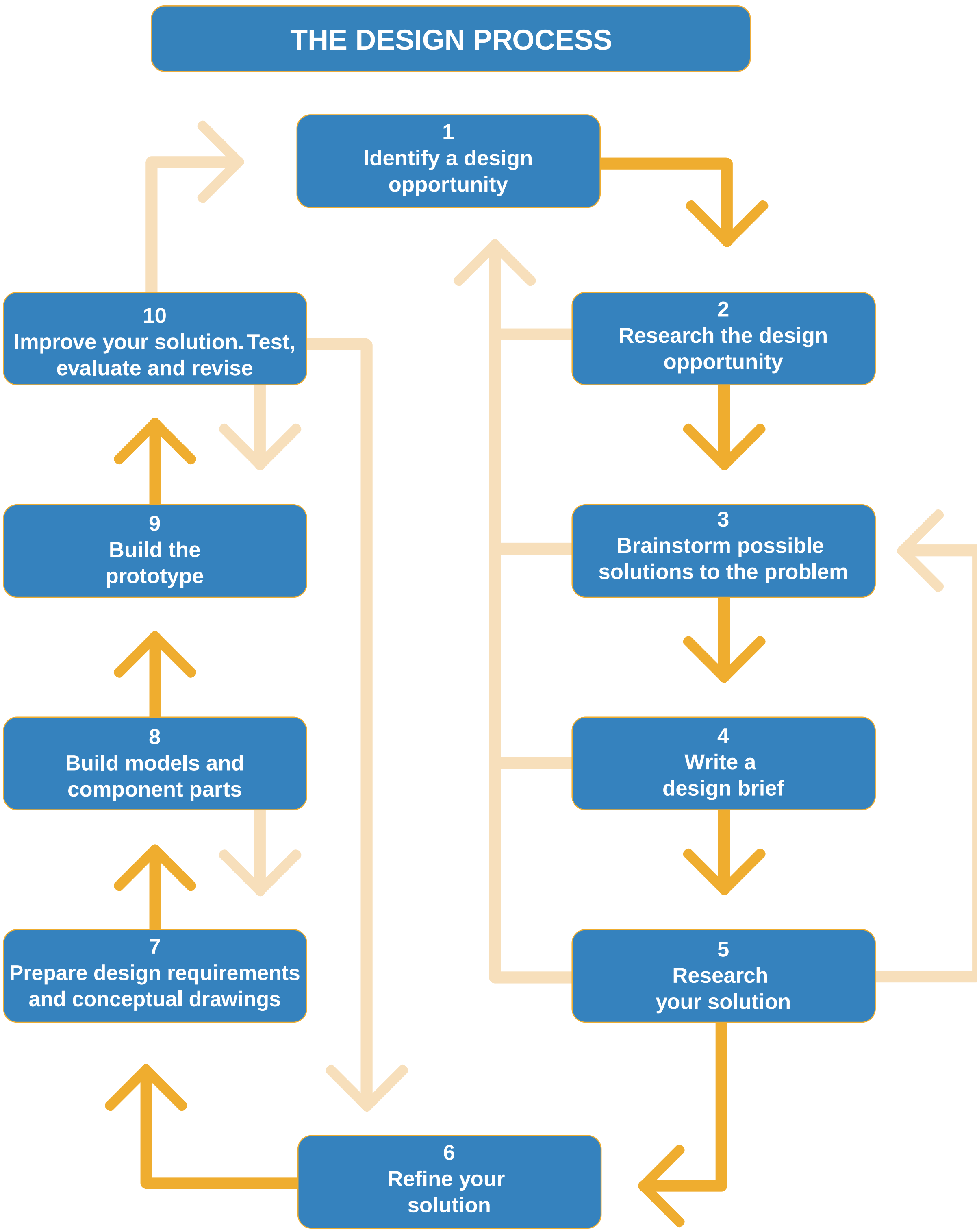
7. **Prepare design requirements and conceptual drawings.**
   Write up the criteria the solution must meet (requirements) and sketch drawings.

8. **Build models and component parts.**
   Analyze the project design for its systems, components, and parts. Now build a model of the entire design and/or its systems.

9. **Build the prototype.**
   Develop project specifications and create a working prototype.

10. **Improve your solution. Test, evaluate, and revise.**
    Evaluate the prototype for function, feasibility, safety, aesthetics, and other criteria. Revise or build another prototype.

1C Worksheet: The Design Process (continued)



Form Follows Fuction- What Does That Mean?

Reading: Session 1, Activity C

The scientist seeks to understand what is; the engineer seeks to create what never was.
—attributed to Theodore Van Karman

Every thing is supposed to function—it's supposed to do something, to work. Engineering is about function: does the product work, does it meet specifications, can it be manufactured efficiently, etc. All of this involves solving problems. We are going to be problem solvers and create things that function; we will think like engineers.

We will also learn the skills of good industrial designers. The *form* of an object (how it is designed and constructed) should follow the task it is to perform. In other words, you must know exactly what you want something to do before you can design and build it. How effectively something *functions* is often related to its *form*, or the quality of its design. Designers are concerned with qualities such as ease of use, efficient operation, and appealing aesthetics. We will pay attention to form in our project development. Though we will not focus on packaging design or marketing aesthetics, we will talk about the subtle but powerful influences of the "visual attraction" and "tactile appeal" of a product. Our goals are to meet an identified need with an idea that could work.

Science, Engineering, and Design: Where Do They Intersect?
While both engineers and scientists experiment and research problems, they differ in the kind of problems they work on. Engineers tend to work on problems that are of immediate concern to many people's daily lives. Scientific problems often build on basic understanding and may not have an immediate application in daily life.

The work of designers and engineers overlaps as well. Both seek to develop solutions to specific and immediate problems and needs. While design is involved in the entire process, engineering is the more specific process of making the idea meet specifications and function. One is useless without the other.

The First Step To a Good Design Is a Good Description Of the Real Problem
The ability to really see a need, and then be able to describe that need, is at the heart of successful product development. It requires a heightened awareness of the way people use things, and an ability to observe one's surroundings. Watching for difficulties people experience in doing a task, or how a particular product is used in an unintended way, takes practice and skill. Our job will be to learn to watch for opportunities for improving a tool or product.

Session 2

Jump into the Designed World II

In This Session:

A The Potato Peeler Upgrades (40 mins)
- Student Reading
- Student Discussion

B SCAMPER and The Potato Masher (40 mins)
- Student Worksheet
- Student Discussion

C Design Opportunities are Everywhere (40mins + H/W)
- Student Worksheet
- Student Discussion

This session builds appreciation for the designed world around us and prepares students for finding a design and engineering project. Students develop skills by thinking creatively about designed things they use. They also learn to identify problems that lead to opportunities for new design solutions. In the first activity, *2A: The Potato Peeler Upgrades,* students learn about and practice a seven-part creative technique for improving existing designs known as SCAMPER. They follow the exercise with a short reading about market research on potato peelers. The next activity, *2B: SCAMPER and The Potato Masher,* reinforces generative thinking using the SCAMPER technique with another object, a potato masher.

The final activity in this session, *2C: Design Opportunities Are Everywhere,* is the first step of students' project development. It involves introducing the Activity Mapping to help students identify problems, and involves a short field trip or walking tour to practice recognizing problems and needs around them. The session ends with students beginning to develop a list of design opportunities that interest them.

A Home Improvement activity, *Improvement Of Everyday Things,* has students make distinctions between functional and superficial improvements with objects in their homes.

Supplies
- Potato peelers in multiple styles
- For each pair of students: 1 standard design potato masher
- Additional potato mashers with other designs
- Clipboards (optional, but handy for taking notes during walking tour)
- Chart paper for posters and markers

Jump Into Design II

Key Concepts: Session 2

In Session 2, students are introduced to two brainstorming techniques. Although many strategies exist to encourage creativity, this session focuses on SCAMPER and Activity Mapping. In this session students practice recognising design problems for themselves. A field trip or even a walk around the school is helpful to get the students thinking about design opportunities. Students should be encouraged to search for design opportunities outside of school e.g. at home, at play, on holiday, while out with family or friends, in clubs or societies they may be members etc., etc. By the end of this session students should have generated a list of design opportunities that interest them.

Key Concepts

SCAMPER
The SCAMPER technique is a brainstorming method that builds one idea into several ideas by asking questions about the actions represented by the SCAMPER acronym. Alex Osborn, an early teacher of creativity, first introduced the idea of using questions to spur idea creation in his book *Applied Imagination.* This technique was later adapted by Bob Eberle and is now used often as a method for new idea generation. Students are introduced to the SCAMPER technique by examining an everyday item - a potato peeler.

Substitute
Combine
Adapt
Minimize/Magnify
Put to other uses
Eliminate/Elaborate
Reverse/Rearrange

Some questions to ask students as they use this technique and some examples to illustrate the concepts are shown below:

Substitute: What can be used instead? What can you use instead of the materials, objects, places or methods now used? Meatless burgers and disposable cameras are examples of products that illustrate substitution.

Combine: Which parts or ideas can you blend together? What could be added? How can I combine uses with something else? Can you combine materials? Scented markers and clock radios are examples of combinations.

Adapt: What else is like this? What can be copied or imitated? How can it be adjusted to fit another purpose? What else is like this? What has worked before? What would you copy? Running shoes and hiking boots are examples of adaptations.

Key Concepts (continued)

Mimimize: Can it be made smaller, lighter, less frequent or divided? How can it be made smaller or shorter? How can it take less time? Mini-staplers and pocket-sized cell phones demonstrate how objects can be minimized.

Magnify: Can it be stronger, larger, higher, exaggerated or more frequent? What happens if I exaggerate a component? How can it be made larger or stronger? What can be duplicated? Repeated? Big-screen televisions and oversized floor pillows illustrate products that have been magnified.

Put to other Uses: Can it be used in a way other that how it was intended to be used? Who else might be able to use it? What other market can it be used in? What else can it be used for other than its original purpose? Old tyres used as swings and drinking cups used as pen and pencil holders illustrate the idea of "put to other uses."

Eliminate: What can you take away or remove? What parts aren't really necessary? Cordless telephones and wireless keyboards are examples of eliminating something.

Rearrange: Can parts be exchanged or the pattern changed? Can any components be interchanged? Can it be laid out differently? Ergonomic keyboards and recumbent bicycles are examples of products that have been rearranged.

Activity Mapping
The Activity Mapping technique allows for keen observation into processes needed to accomplish a certain activity. Describing four process stages in detail helps determine if any design opportunities might exist.

Key Concepts (continued)

More about the Design Process and Brainstorming

Garratt, James. *Design and Technology.* New York: Cambridge University Press, 1993.

Petrowski, Henry. *Invention by Design; How Engineers get from Thought to Thing.* Cambridge: MA: Harvard University press, 1998.

Petroski, Henry. *To Engineer is Human: The Role of Failure in Successful Design.* Reprint, New York: Vintage Books, 1992.

Eberle, Bob. *Scamper: Games for Imagination Development.* Waco, TX Prufrock Press, 1996. This book provides a description of SCAMPER and also activities that can be used with students to practice the technique.

Eberle, Bob. *Scamper On. Waco*, Tx: Prufrock Press, 1997.
This book provides more guided activities encouraging students to think in creative ways.

IDEO. *IDEO Method Cards: 51 Ways to Inspire Design*. San Francisco: William Stout Architectural Books, 2003.
www.ideo.com/methodcards/MethodDeck/index.html*
IDEO, a design firm, publishes cards illustrating methods to inspire innovative ideas. Sharing these methods with students will provide additional ways to look creatively at design solutions.

Michalko, Michael. *Cracking Creativity: The Secrets of Creative Genius.* Berkeley, CA: Ten Speed Press, 1998.
This book provides creative thinking strategies, stories and exercises to use with students.

Michalko, Michael. *Thinkpak: A Brainstorming Card Deck.* Berkeley, CA: Ten Speed Press, 1994.
ThinkPak is a deck of cards focusing on the SCAMPER technique. the cards may be used to develop new and innovative ideas through the practice of the SCAMPER technique.

Osborn, Alex. *Applied Imagination.* New York: Scribners, 1953.
This book discusses the idea of brainstorming and the study of creativity. This book influenced the development of creative thinking techniques and idea generation.

Session 2, Activity A

The Potato Peeler Upgrades

In This Session:

Goal

Introduce and practice SCAMPER, a creative technique for improvement of existing designs.

Outcome

Learn and practice the SCAMPER process. (see page 39)

Description

Students learn about and use SCAMPER, a systematic technique for generating ideas about improving existing designs. They study a potato peeler and try to create ideas about designing an improved peeler.

Substitute
Combine
Adapt
Minimize/Magnify
Put to other uses
Eliminate/Elaborate
Reverse/Rearrange

Supplies

- Potato peelers in multiple styles
- Clipboards (optional, but handy for taking notes during walking tour)
- Chart paper for posters and markers

Preparation

1. Read through the SCAMPER technique for expanding thinking about improvements.
2. Practice using SCAMPER to come up with an improvement yourself!

Intel Education

2A: The Potato Peeler Upgrades (continued)

Procedures

1. Distribute potato peelers among groups of students.
2. Present each step of the SCAMPER process using a potato peeler as an example.
3. Assign a different letter of SCAMPER to seven groups and have them create and display posters of the SCAMPER technique using the letters and keywords from the worksheet.
4. Discuss each step individually and encourage participants to apply and share the step to the potato peeler example they have.
5. Provide time for participants to study different potato peelers and think of improvements as a group.
6. Together, compare two different peeler designs and determine which step of SCAMPER was applied.

Wrap Up

Discuss any other strategies for generating new ideas and approaches to existing solutions.

Follow With

Activity *2B: SCAMPER and The Potato Masher* applies the SCAMPER technique to another household device, the potato masher.

The Potato Peeler Upgrades

Worksheet: Session 2, Activity A

Ready to SCAMPER? SCAMPER is a technique that gets you to think about improving an existing design. It is an acronym that helps you remember seven different ways to think up new improvements. It is useful for being creative in a systematic way. It generates ideas you might not have on your own. Try it!

S Substitute one thing for another.

C Combine with other materials, things, or functions.

A Adapt: Can it be used for something else?

M Minimize/Magnify: Make it larger or smaller.

P Put to other uses: Can you put it to another use? In this case, use it for another vegetable? If you make it larger, would it work for some other food?

E Eliminate/Elaborate: Remove some part or material, or make one section more detailed or refined.

R Reverse/Rearrange: Flip-flop some section of the item, move parts around.

SCAMPER	Peeler Improvement	Benefit
Substitute	Different handle material	Rubber handle, more comfortable to hold
Combine	Combine peeling with other functions	Peeler with potato scrubbing brush
Adapt	Adapt peeler for other uses	Potato, carrot, and asparagus peeler
Magnify/ Minimize	Longer cutting edge on blade	Better for peeling large potatoes
	Fold-away blade	Safer when stored in drawer
Put to other uses	Larger and sharper blade	Can be used for food with thicker skin
Eliminate/ Elaborate	Eliminate plastic. Have one-piece metal peeler rolled to form handle.	Striking all-metal appearance
	Curved blade	Fits round curved surface of potato
Rearrange/ Reverse	Blade angled at 120º to handle	Better ergonomics for peeling
	Gouge at base of handle instead of at tip of blade	Easier to use

Adapted from: Baxter, Mike. *Product Design: Practical Methods for the Systematic Development of New Products,* 1st ed. Cheltenham, United Kingdom: Stanley Thornes, 1995.

Session 2, Activity B

SCAMPER and The Potato Masher

Goal

Apply the SCAMPER technique to the components of a potato masher.

Outcome

Improve the three main components of a standard potato masher using SCAMPER.

Description

Students look at the different components of the potato masher and apply the SCAMPER technique to each of them. They are introduced to technical drawing by enhancing an existing drawing with their improvements.

Supplies

For each pair of students: 1 standard design potato masher
Additional potato mashers with other designs

Preparation

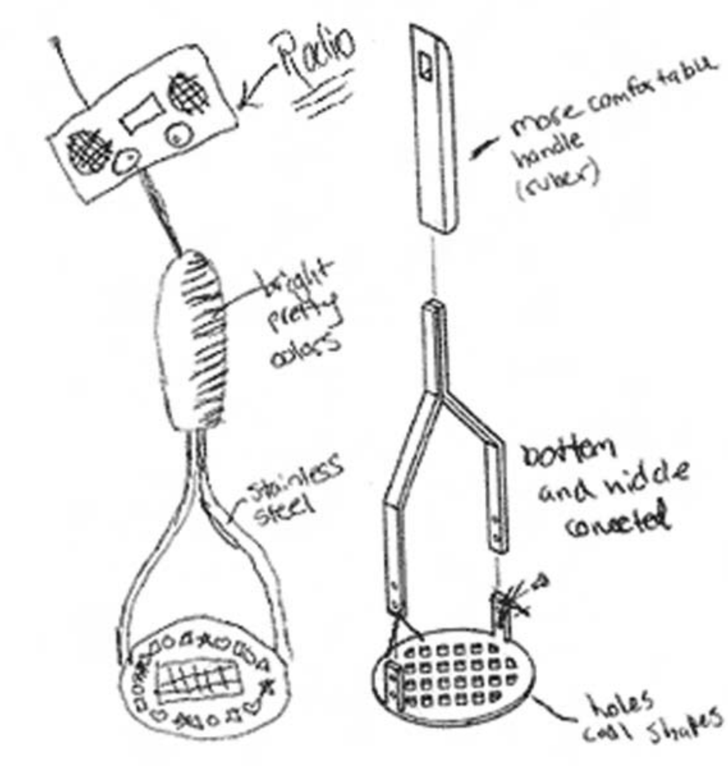
Make at least two extra copies of the drawing of the potato masher per student, for adding enhancements.

Procedures

1. Distribute potato mashers and handouts to students.
2. Ask the students to compare the potato masher to the technical drawing.
3. Call attention to the three components of the potato masher:
   Notice how a product can be broken down into parts.
   Notice how the drawing separates the parts but indicates attachment points between parts.
4. Walk through the first two letters of SCAMPER as a group, and then continue the process in teams.
5. As they work through the process, encourage students to sketch and make notes about possible improvements in their design notebooks.

2B: SCAMPER and The Potato Masher (continued)

7. Have them draw improvements on the worksheet that shows a technical drawing of a standard potato masher.



Wrap Up

Share improvement ideas for each SCAMPER letter and discuss:

- What component was improved or used differently?
- What idea comes to mind first?
- How many ways do you think this product could be changed?

Follow With

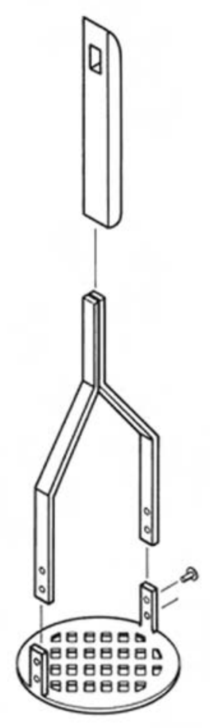
Activity 2C: Design Opportunities Are Everywhere generates ideas for design projects from a field trip or walking tour of a public space.

SCAMPER and The Potato Masher

Worksheet: Session 2, Activity B

The Potato Masher, Improve It!

Apply SCAMPER to each of the potato masher parts. Sketch and make notes about your improvement ideas. Draw your best ideas on this technical drawing of the standard potato masher.



Session 2, Activity C

Design Opportunities are Everywhere

In This Session:

Goal

Learn to identify problems, needs, and opportunities for design improvements.

Outcome

Students generate a list of 10 problems that they see as opportunities for design solutions.

Description

This activity begins the students' project development. It should expand their awareness into many possible opportunities for designed solutions. The activity introduces another brainstorming technique, the Activity Mapping where students identify an activity, think about the steps in this activity, and consider where there could be room for improvement. Following this, a short field trip or walking tour is a preferred method to give students ideas for design opportunities. This outing can be as simple as a walking around the school. Students should be encouraged to take every opportunity to look for design opportunities, around their homes or when they are out with their friends. A field trip to any convenient public place such as a department store or a mall will work well.

Students collect their observations and information about problems and select 10 that present opportunities for designing new solutions. Students will revisit and refine this list of problems and begin to work on solutions in Sessions 8 and 9.

2C: Design Opportunities are Everywhere (continued)

Procedures
ZIBA Design Activity Mapping

1. The Activity Mapping is used as a way to identify processes, the products used in the processes, and identify problems in the processes. Model strategies for identifying problems by introducing the Activity Mapping. This technique is used by ZIBA Design, http://www.ziba.com*, an international design firm that has designed products for many global companies, including FedEx, Microsoft, Intel, Fujitsu, Black & Decker, Sony, Pioneer North America, Dial, and Clorox. Students practice using a Activity Mapping with a group example, using teeth brushing.

2. Explain that the Activity Mapping has four primary user goals that summarize what people are trying to accomplish when engaging in an activity.

   Activity Mapping

   1. Pre-activity: Describes what is done before the activity
      ↓
   2. Activity: Explains what is involved in the activity
      ↓
   3. Post-activity: Includes what is involved after the activity
      ↓
   4. Assessment: Involves how one knows if the activity has been successful

2C: Design Opportunities are Everywhere (continued)

3. Using chart paper, ask students what is involved for each phase of brushing teeth. In the example below, “prepare” is the pre-activity, “mouth cleaning” is the activity, and “cleanup” is the post-activity, The Activity Mapping should look something like this:

Prepare	Get Paste Locate Brush Wet Brush Load Brush Cap Paste
↓ Mouth Cleaning	Brush Upper Lower Interior Exterior Tongue
↓ Cleanup	Spit Rinse Mouth Rinse Hands Wipe Mouth Dry Hands Store Brush Store Paste
↓ Assessment	Mouth Feels Clean Looks Good Tastes Good

Four primary user goals summarize what people are trying to accomplish when engaging in daily oral care.

Prepare
Preparation involves all the tool preparation steps that need to be done before users actually brush their teeth.

Mouth Cleaning
Mouth cleaning begins when the cleaning surfaces of the toothbrush are applied to the inside of the mouth. This is the active part of the brushing, where all efforts are physically focused on the removal of food debris, night films, mouth freshening, and gum maintenance.

Cleanup
Cleanup has three elements: tool maintenance, tool storage, and personal rinsing. Tool maintenance is focused primarily on getting brushes, sinks, and toothpaste rinsed and ready for next use. Tool storage involves keeping a bathroom tidy and getting the brush, paste, cups, etc. to a safe place where they are less likely to be contaminated. Personal rinsing refers to removal of saliva and paste from the mouth and hands. Rinsing is followed by towel drying.

Assessment
Assessment allows users to determine whether they’ve accomplished their personal goals with respect to mouth cleaning. Methods include visual inspection in the bathroom mirror, tactile inspection with the tongue, and self-perception of a minty mouth and fresh breath.

4. Ask students what products are involved in each process. Ask them to consider if there are any problems with any of these products, any suggestions they have for improving a product, or inventing a new product. What could make life easier for people when they brush their teeth? Explain that this is one way to identify problems and begin to consider solutions.

2C: Design Opportunities are Everywhere (continued)

5. Students can apply this tool to identifying other problems and ultimately coming up with solutions.

Wrap Up

Introduce the Home Improvement Activity, *Improvement Of Everyday Things.*

Follow With

Session 3 Material Science where students learn about materials and the principles behind material selection.

Design Opportunities are Everywhere

Worksheet: Session 2, Activity C

Problem Identification: What Makes a Good Problem To Solve?

Many important engineering and design ideas start with a problem or need. You have the capacity to solve important problems, and make amazing things happen. Good ideas are inside you. Good problems often start with things you know about or have some personal connection to. Perhaps it's something that bothers you and you think about how it could be different. Maybe you have a relative or friend who struggles with something. Sometimes a problem to solve just comes from an idea of yours that sounds like a fun or easier way to do something.

In this activity, you will practice identifying design opportunities. Some of these opportunities may be problems while others may be needs, or simple improvements.

Who knows about problems? What kinds of problems are there?

- Health problems: Doctors and nurses would know, researchers too.
- Safety problems: Emergency room staff would know, firemen and police would know.
- Problems of a specific group: The elderly, the very young, people in wheelchairs, left-handed people, short people, deaf people. Try to understand through experience what it would be like to be in their shoes. Research the associations or organizations of these groups.
- Inconvenient problems: What bugs you? Always losing your keys?

Make a list of the people or organizations you could call for more information about problems or things that don't work well enough:

2C: Worksheet: Design Opportunities are Everywhere (continued)

ZIBA Design Activity Mapping
As a group, you'll do a practice Activity Mapping. This is a useful tool for identifying problems. The Activity Mapping has four primary user goals that summarize what people are trying to accomplish when engaging in an activity.

Activity Mapping

1. Pre-activity: Describes what is done before the activity
↓
2. Activity: Explains what is involved in the activity
↓
3. Post-activity: Includes what is involved after the activity
↓
4. Assessment: Involves how one knows if the activity has been successful

Now, do your own Activity Mapping for a problem that you identify. This can be done in your design notebook.

Where Can You Find Problems To Solve?
The answer is: everywhere. With attention and focus on designed things you see and use wherever you go, you will see all kinds of problems just waiting for your ideas and creativity. You will be taking a trip today to observe a public place (a mall, a park, or a store). *Look for problems to solve.* Watch how people use things in that place. *Look for problems to solve.* Study a few objects and items in that place. *Look for problems to solve.* Take notes:

2C: Worksheet: Design Opportunities are Everywhere (continued)

What Problems Would You Like To Solve?

They can be big problems or small problems. You decide. Creativity takes practice and patience. And it takes a few good strategies. One strategy is called "brainwriting." Brainwriting is different from brainstorming because you don't talk. You write your ideas on paper, quietly.

Write down 10 "problems" you are aware of (these may be from the field trip). Include things that exist that could use improvement. Write this list in your design notebook or in the space below.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

Save this list. Revisit it as you work through the other *Design and Discovery* sessions. Add new design opportunities as you think of them.

Notes:

Session 3

Material Science

In This Session:

A Properties of Materials (80 mins)
- Student Worksheet
- Student Reading (H/W)

B Materials Applications (20 mins)
- Student Worksheet

C Material Choice (20 mins)
- Student Worksheet

D Do Materials Matter? (H/W)
- Student Worksheet

From spacecraft to ball point pens, materials make the difference in successful performance of a product. In this session students learn about four different classes of materials and test them to understand their properties. They apply selection criteria to determine the best materials for different applications, while learning to consider the cost and environmental impact when choosing materials. Like materials engineers, students learn to differentiate and select materials based on their properties.

In *3A: Properties of Materials,* students test samples of metals, ceramics, polymers, and composites to compare their properties. They test for density, ductility, strength, fatigue, electrical and thermal conductivity, and optical properties. In *3B: Materials Applications,* students apply their knowledge of material properties to solve real-world problems faced by materials engineers. When materials engineers select which materials to use, they also consider materials cost and in *3C: Material Choice,* students gain an understanding of the economics of material selection through a cost analysis of a beverage container made of different materials. They then think innovatively about how to design a beverage container that can be put to another use.

Supplies

For demonstration:
- Chart Paper.
- A brick, a block of wood, and a block of Styrofoam*.
- 2 Chocolate bars with caramel filling (1 frozen; 1 room temperature)

For each small group:
- 1 wooden popsicle stick, 1 plastic eating utensil, 1 metal eating utensil, 1 piece of tile
- 8x1 strips of Aluminium foil, heavy duty zip lock Ziploc* plastic bags, paper, 2 buckets (10 litre and 5 litre), 2 kg of sand, rice, or beans (as weights), 2 C-clamps
- plastic multipurpose cable tie, 16-18 gauge copper or aluminium wire (or steel paper clips) cut to same size as tie, small piece of thin plywood (approx. 5 mm thick).
- candle, matches
- battery, wire, bulb
- flashlight, samples of transparent (plastic bag), translucent (plastic cup—hazy type), and opaque (colored plastic bucket)
- 1 of each for each group: 330 ml glass, aluminium and plastic beverage containers

intel Education

Material Science

Key Concepts: Session 3

Session 3 is about materials. In order to select suitable materials for use in a product, it is important to know the differences between the classes of materials and their related properties. Students need to build familiarity with material classes, material properties, how materials are selected and used, how cost is considered and the environmental impact of materials.

Key Concepts

Materials are so important to engineering and design that there is a whole field of engineering devoted to materials. Materials engineers envision, design, prototype and test new or modified materials for products. They provide expertise on materials selection and properties for a given product. Some materials engineers develop materials processing methods and even create new materials.

Classes of Materials

Materials are grouped into categories or classes based on their chemical composition. Material selection is determined by the capabilities and qualities of materials or their properties. A chart on page 70 shows four classes of materials, their definitions, types of materials within each class, properties and examples of usage.

Properties of Materials

A chart on material properties is shown on page 70.

Costs of Materials

Materials are usually sold by weight or by size. Material costs are therefore given as cost per unit weight or cost per unit volume. Many materials are initially made in bulk (such as cast metal ingots). They are usually shaped into standard stock items (for example, a sheet or tube) before being bought by a manufacturer. As a result, the cost of a material to a manufacturer is often higher than the cost of the raw material. Also, as a general rule, the more a material is "improved," for example by alloying, the more expensive it becomes.

Material costs are not fixed, but are strongly affected by the marketplace and international trading and by changes in the stability of the supply of the raw materials - which can be disrupted by wars and global politics. Some materials, such as steel, have had a very stable price for many years. The price of others, like aluminium, have varied by more than a factor of 3 in the last decade. The cost of newer materials steadily decreases as their usage increases. The most accurate information on material price can be obtained by contacting material suppliers. Note that the price will depend on the form the material is supplied in (as a raw material, or formed into a sheet or tube), and that bulk discounts can be significant.

Key Concepts (continued)

Materials Recycling

Aluminium Recycling: Aluminium is easily and frequently recycled. It is sorted at a sorting plant using magnets that separate steel and aluminium. Aluminium is a chemical element that cannot be found in the earth in its pure form. Therefore, extraction becomes quite a complex and energy-intensive process that takes aluminium oxide from bauxite and then removes the oxygen in a smelting process to produce aluminium. the recycling of aluminium is relatively easy, and saves up to 95 percent of the energy required to refine it after original extraction. This significantly increases the need for keeping refined aluminium within the material stream rather than letting it become waste, thereby placing a premium on its recycling.

Glass Recycling: Glass is a highly effective recycled material and a very stable, nontoxic material when disposed of. Glass recycling is heavily dependent on the appropriate colour separation of the material. In addition to colour considerations, glass recycling must remove other impurities that are common, such as porcelain, ceramics, cork and paper from labels, which all cause problems in the subsequent manufacturing process.

Paper Recycling: The recycling of paper and cardboard is the most easily attained and most effective. The quantity of paper recycled has increased. The quality of paper recycling depends on the process used. Paper cannot be recycled forever. each process reduces the fibre length, thus reducing the ability of the fibres to stick together without the use of additional adhesives.

Plastics Recycling: The primary problem with plastics recycling is cross-contamination of resins. If one type of plastic is recycled with another, it can significantly degrade the quality of the end product. therefore, a careful process of sorting is required to ensure this does not occur. There are different methods used to sort plastics. Once the material has been sorted, it can be remanufactured using a number of different techniques including extrusion, blow molding and injection molding and reused in many different applications. Certain packaging functions do not allow the use of recycled materials, particularly packaging of foodstuff.

The Plastic Coding System

The use of coding facilitates sorting for plastic recycling. It ensures that plastic containers and materials of various resin types can be identified so that they can be properly collected, sorted and recycled. Plastics are numbered 1-7 based on their material composition.

Key Concepts (continued)

Type of Plastic	Common Uses
1 = PET or PETE = Polyethylene terephthalate	Soft drink, fruit juice, alcohol beverage bottles
2 = HDPE = High Density polyethylene	Clear HDPE – milk jugs, distilled water and large vinegar bottles and grocery bags Coloured HDPE – Liquid laundry and dish detergent, fabric softener, motor oil, antifreeze, bleach and lotion containers
3 = V or PVC = Vinyl/polyvinyl chloride	Vegetable oil, mouthwash and salad dressing bottles
4 = LDPE = low density polyethylene	Food storage containers and bags for dry cleaning, bread, produce and trash
5 = PP = Polypropylene	Battery cases, dairy tubs and cereal box liners
6 = PS = Polystyrene	Yoghurt cups, clear carryout containers, vitamin bottles, fast food spoons, knives and forks, hot cups, meat and produce trays and egg cartons
7 = Other types of plastics	Squeezable ketchup containers, most crisp snack bags and juice boxes (individual servings)

More About Materials

American Plastics Council, www.americanplasticscouncil.org*
This site provides everything that you ever wanted to know about plastics.

Materials World Modules, www.materialsworldmodules.org*
These modules provide more in-depth activities for students and can be ordered from Northwestern University.

Design inSite, www.designinsite.dk*
This danish Website is a designer's guide to manufacturing. It provides information about materials, materials properties and material use in products.

Demi Guide to Sustainability, www.demiorg.uk*
This guide explores design for sustainability, environmental issues of design, and how to design materials and products with sustainability in mind.

Inquiring Minds, www.tvo.org/iqm/site_contents.html*
This site provides clear explanations and pictures that make learning about plastics easy. The site also includes short videos, for example, How Velcro Works.

Session 3, Activity A

Properties of Materials

Goal
Understand the classes of materials and be able to differentiate materials based on their properties.

Outcome
Students know the properties of four different classes of materials.

Description
Students test samples of metals, ceramics, polymers, and composites to compare their properties. They test for density, ductility, strength, fatigue, electrical and thermal conductivity, and optical properties.

Supplies
As on page 55

Safety Issues
Be sure to have students use safety precautions when testing materials. In the thermal conductivity test, students use candles to heat materials. Be sure that they do not put the materials too close to the flame. This can also be done as a demonstration.

3A: Properties of Materials (continued)

Preparation

1. Familiarize yourself with the different classes of materials (see chart on page 70).

2. Conduct the properties tests yourself.

3. Distribute supplies to each pair or group. Decide if students will do all the tests first and then discuss the results or if a discussion will take place after each test.

Testing Material Properties

1. To understand material properties, student run tests comparing materials. These can be done in pairs or small groups.
2. Be sure to explain that understanding material properties will help students when planning what materials to use for their projects. They will be able to select materials that make the most sense for their required use.
3. After each test, students should consider examples of objects where that property characteristic is important.

Materials Test 1: Density Test

1. Question: What materials are more dense?

2. Materials: a brick, a block of wood, and a block of Styrofoam

3. Explain: Discuss what density is. *Density is a measure of how heavy an object is for a given size, i.e. the mass of material per unit volume. The formula to determine density is:*

$$Density = \frac{Mass}{Volume} \ g/cm^3$$

4. Test: Show an example of how to use the formula. Find the volume of the material (cm^3). Regular shape (LxWxH). Irregular shape (Measuring cylinder). Find mass of material on electronic balance (g). Then use the formula to determine the density of each object.

5. Rate: Rate the density of the materials: high, medium, or low density.

6. Discuss design issues: Think of examples of other objects where high density is important *(paperweight, building material).* Think of examples of objects where low density is important *(baseball bat, tennis racket, backpack.)*

3A: Properties of Materials (continued)

Materials Test 2: Ductility vs Brittleness Test

1. Question: How easily does it stretch when force is applied?

2. Materials: For optional demonstration: 2 chocolate bars with caramel filling (1 frozen; 1 room temperature). For testing: 1 wooden popsicle stick, 1 plastic eating utensil, 1 metal eating utensil, 1 piece of tile.

3. Demonstration (Optional): To demonstrate the concept of ductility, break chocolate bars one at a time. What happens? Does it bend or crack first? *(The unfrozen bar will stretch and bend before breaking [ductile], while the frozen one will not stretch but rather break immediately [brittle]).*

4. Test: Bend the wooden popsicle stick, a plastic utensil, and a metal utensil. What happens? Which one is most ductile?

5. Rate materials from the most ductile to the least ductile. *(The plastic utensil will stretch and easily return to its original form and is therefore the most ductile; the wooden stick will bend, but will not return to its original form; the metal will be hard to bend and is less ductile; and the ceramic tile will snap and break and is therefore the least ductile).*

6. Discuss design issues: Ductility is important in designing products which can only be allowed to bend by a certain amount *(bridges, bicycles, furniture)* or that need to be flexible when used and return to their original shape when not in use *(rubber bands, plastic shopping bags)*. Ductility is also important in springs, which store energy *(vaulting poles, bungee ropes.)* Brittleness is important for objects that maintain their shape regardless of how much force is applied *(ceramic floor tile, wooden shelves).*

Materials Test 3: Strength Test (Tensile Test)

1. Question: How much weight can it hold without failing or breaking?

2. Materials: 8x1 strips of aluminium foil, heavy duty zip lock Ziploc plastic bags, paper, 2 buckets (10 litre and 5 litre), 2 C-clamps, some weights (e.g. newton weights).

3. Test: Before assembling the materials, weigh the individual materials. Attach a bucket with a G-clamp to the material to be tested and attach the material with a G-clamp to a table. Be sure to have a larger bucket below to catch the weights. Fill the bucket slowly with weights. How much weight will it take until the material breaks? Record results and compare.

3A: Properties of Materials (continued)

4. Rate materials: strong, medium, and weak in strength
5. Explain: It may be surprising that paper is so strong. This is a good place to explain more about composites. Composites are two or more distinct substances that are combined to produce a new material with properties not present in either individual material. Composites are often made to create a stronger material. For example, plywood is a composite. Thin sheets of wood are stacked and glued so that the end product is stronger than each material on its own.
6. Discuss design issues: Material strength is important in structural applications *(brick, stone, and concrete for bridges and buildings.)* Material strength is also important in transportation applications *(airplanes, cars, bicycles.)*

Materials Test 4: Fatigue Test

1. Question: How much repeated stress can cause the material to fail or break?
2. Materials: plastic multipurpose cable tie, copper or aluminium wire (or steel paper clips work well) cut to same size as tie, small piece of thin plywood.
3. Test: Bend each item back and forth as you count how many times it takes to break. Record the times. Be sure that students use the same amount of strength or stress when bending the material back and forth over and over. *As strength varies from student to student, the participants should recognize that there may be variety in the data collected.*
4. Rate materials: high, medium, low. *(most turns=high fatigue resistant)*.
5. Discuss design issues: For what objects is fatigue important? *(Anything used repeatedly –paper clip, eating utensils, bridges, airplane wings)* For what objects is material fatigue not important? *(Anything that is disposable or anything that doesn't experience repeated stresses – plastic eating utensil).*

Materials Test 5: Electrical Conductivity Test

1. Does electricity pass through the material easily?
2. Materials: battery, wire, bulb, aluminium foil, cardboard, plastic bag, ceramic tile.
3. Test: Make an electrical circuit with each material and see if the bulb lights.
4. Rate: yes or no if the bulb lights

3A: Properties of Materials (continued)

5. Discuss design issues: When is it important to use a material that conducts electricity? *(When an electrical charge needs to be transported.)* When it is important to use a material that does not conduct electricity? *(Anything that covers electrically conductive material – plastic on TV, plastic around wire on electrical cord)*

Materials Test 6: Thermal Conductivity Test

1. Question: Does heat pass through it easily?

2. Materials: candle, matches, same material as above

3. Test: Investigate the ability of materials to transmit heat by holding each material about a few inches from the candle flame for 10 seconds. Take the material away from the flame and compare how hot it is and how long it stays hot. A material that is very hot and remains hot for awhile, has higher thermal conductivity than a material the does not feel hot and cools quickly. Record results and repeat.

4. Rate: high conductivity, medium, low *(aluminium – high, ceramic – medium, paper – medium, plastic – low)*

5. Discuss design issues: Thermal conduction is the passage of heat through a material, such as metal. Thermal insulation is a barrier to the conduction of heat. Knowing how conductive a material is helps determine if the material is suitable to include in home construction, clothing, sports shoes, cooking products, and spacecraft design, for example. What are examples of objects that need a material that is a thermal conductor? *(baking sheets, heating radiators.)* When is the use of insulation materials necessary? *(polystyrene and paper cups for hot drinks.)*

3A: Properties of Materials (continued)

Materials Test 7: Optical Properties Test

1. Question: How easily does light pass through it? (Transparent, translucent, opaque)

2. Materials: flashlight or bulb and battery, samples of transparent (plastic bag), translucent (plastic cup—hazy type), and opaque (coloured plastic bucket)

3. Test: Compare materials by shining a light through them.

4. Rate: transparent, translucent, opaque

5. Explain: Light passes through transparent materials, and images can be viewed through them. Light passes through a translucent material; however, images cannot be seen easily or at all through the translucent material. Light cannot pass through an opaque material, and images cannot be seen through them.

6. Discuss design issues: What are examples of objects made that are transparent *(car windshields, eyeglasses, plastic food containers)*, translucent *(bathroom windows—very often for privacy, glass mugs for decoration, some curtains),* and opaque *(room darkening curtains or blinds, sunscreens for car windshields)*? When are these properties important? Help the students find examples of these three characteristics in materials or objects where the passage of light and viewing of objects matters and may or may not be desired. In many cases, optical materials are chosen for their aesthetics and not properties.

Wrap Up
Review students' charts and check for understanding.

Follow With
The next activity, *3B: Materials Applications*, students apply problem-solving skills to real-world material problems.

Material Class and Properties

Worksheet: Session 3, Activity A

Materials engineers design new materials and determine what materials are best used for certain structures and devices. They determine this by understanding the properties of materials so that they can select the most appropriate material or combination of materials for a particular use.

In this activity, you will test materials to learn about their properties. After each test, rate each material that you tested in the chart on this page. For each property, come up with examples of objects where each property is important.

Density Test

1. Question: What materials are more dense?

2. Materials: a brick, block of wood, and block of Styrofoam, ruler, balance and measuring cylinder.

3. Test: Compare the density of a brick, a block of wood, and a block of Styrofoam.
   Find the volume of the material (cm^3). Regular shape (LxWxH). Irregular shape (Measuring cylinder).
   Find mass of material on electronic balance (g).
   Calculate density

$$Density = \frac{Mass}{Volume} \; g/cm^3$$

Record your results in the chart below

Material	Length(cm)	Width(cm)	Height(cm)	Volume (cm^3)	Mass (g)	Density (g/cm^3)
Brick						
Wood						
Styrofoam						

4. Rate: Rate the materials according to their density (high, medium, low).

5. Discuss design issues: Think of examples of other objects where high density is important. Think of examples of objects where low density is important.

3A Worksheet: Material Class and Properties (continued)

Ductility vs Brittleness Test

1. Question: How easily does it stretch when force is applied?
2. Materials: For optional demonstration: 2 chocolate bars with caramel filling (1 frozen; 1 room temperature). For testing: 1 wooden popsicle stick, 1 plastic eating utensil, 1 metal eating utensil, 1 piece of tile.
3. Test: Bend the wooden popsicle stick, a plastic utensil, and a metal utensil. What happens? Which one is most ductile?
4. Rate materials from the most ductile to the least ductile.
5. Discuss design issues: Ductility is important in designing products which can only be allowed to bend by a certain amount or that need to be flexible when used and return to their original shape when not in use. What are examples of applications where ductile materials are needed?

Strength Test (Tensile Test)

1. Question: How much weight can it hold without failing or breaking?
2. Materials: 8x1 strips of aluminium foil, heavy duty zip lock Ziploc plastic bags, paper, 2 buckets, 2 kg of sand, rice, or beans (as weights), 2 C-clamps
3. Test: Before assembling the materials, weigh the individual materials. Attach a bucket with a C-clamp to the material to be tested and attach the material with a C-clamp to a table. Be sure to have a larger bucket below to catch the weights. Fill the bucket slowly with weights. How much weight will it take until the material breaks? Record results and compare.
4. Rate materials: strong, medium, weak in strength.
5. Discuss design issues: Material strength is important in structural applications. What are examples of this? Material strength is also important in transportation applications. What are examples of this?

3A Worksheet: Material Class and Properties (continued)

Fatigue Test

1. Question: How much repeated stress can cause the material to fail or break?

2. Materials: plastic multipurpose cable tie, copper or aluminium wire (or steel paper clips) cut to same size as tie, small piece of thin plywood.

3. Test: Bend each item back and forth as you count how many times it takes to break. Record the times. Be sure that students use the same amount of strength or stress when bending the material back and forth over and over.

4. Rate materials: high, medium, low. (most turns=high fatigue resistant)

5. Discuss design issues: For what objects is fatigue important? For what objects is material fatigue not important?

Electrical Conductivity Test

1. Does electricity pass through the material easily?

2. Materials: battery, wire, bulb, aluminium foil, cardboard, plastic bag, ceramic tile – all 1x8 with the same thickness

3. Test: Make an electrical circuit with each material and see if the bulb lights.

4. Rate: yes or no if the bulb lights

Record your results in the chart below

Material	Aluminium	Cardboard	Plastic	Ceramic
Bulb Lights?				
Conductor/ Insulator				

5. Discuss design issues: When is it important to use a material that conducts electricity? When it is important to use a material that does not conduct electricity?

3A Worksheet: Material Class and Properties (continued)

Thermal Conductivity Test

1. Question: Does heat pass through it easily?

2. Materials: candle, matches, same material as above

3. Test: Investigate the ability of materials to transmit heat by holding each material about a few inches from the candle flame for 10 seconds. Take the material away from the flame and compare how hot it is and how long it stays hot. A material that is very hot and remains hot for awhile, has higher thermal conductivity than a material the does not feel hot and cools quickly. Record results and repeat.

4. Rate: high conductivity, medium, low

5. Discuss design issues: What are other examples of objects that need a material that is a thermal conductor? When is the use of insulation materials necessary?

Optical Properties Test

1. Question: How easily does light pass through it? (Transparent, translucent, opaque)

2. Materials: flashlight or bulb and battery, samples of transparent (plastic bag), translucent (plastic cup—hazy type), and opaque (colored plastic bucket)

3. Test: Compare materials by shining a light through them.

4. Rate: transparent, translucent, opaque

5. Discuss design issues: What are examples of objects made that are transparent, translucent, and opaque? When are these properties important?

3A Worksheet: Material Class and Properties (continued)

Property	Definition
Density	How heavy objects are that occupy the same volume.
Ductility	How easily a material stretches when force is applied.
Strength	How much weight a material can hold without failing or breaking.
Fatigue	How easily a material withstands repeated stresses.
Electrical Conductivity	Whether or not electricity passes through the material.
Thermal Conductivity	How easily heat passes through the material.
Optical Properties	How easily light passes through (transparent, translucent, opaque)
Corrosion	If the material degrades easily because of the physical environment.

Material	Density (High, Medium, Low)	Ductility (High, Medium, Low)	Strength (Strong, Medium, Weak)	Fatigue Prone (High, Medium, Low)	Electrical Cond. (Yes/No)	Thermal Cond. (High, Medium, Low)	Optical (Transparent, Translucent, Opaque)
Metal							
Polymer							
Ceramic							
Composite							
Example							

Material Class and Properties

Reading: Session 3, Activity A

From the Stone Age to the Information Age, humans have made use a wide array of materials to improve their lives. Stroll through the halls of a museum and you will see that major epochs have been shaped and even defined by certain materials. From iron and steel to textiles and microprocessors, materials have a seemingly infinite range of properties and applications.

Not surprisingly, the field of materials science covers a wide range of disciplines. Materials engineers contribute to the field by evaluating materials for how well they distribute stress, transfer heat, conduct electricity, and meet other design specifications.

New materials are constantly being invented, and new uses for existing materials continue to emerge. In recent years, for example, researches from Nike have figured out how to grind up used athletic shoes and create a new material for resurfacing running tracks and basketball courts. Researchers from Patagonia have developed a method to reuse the plastic in soda bottles to make a synthetic fiber that is spun into soft fleece for making sportswear.

Let's take a look at four of the major classes of materials.

Materials Class	Definition	Examples	Properties	Applications
Metals	Metals are materials that display certain properties such as a metallic lustre and the capacity to lose electrons and to form positive ions. When a metal is mixed with another metal or non-metal, the substance formed is called an alloy.	**Pure metals:** aluminium iron lead copper silver gold platinum **Alloys:** *steel (iron+carbon) brass (copper+zinc) bronze (copper+tin)	strong dense ductile opaque good conductors of heat and electricity	electrical wiring, structures (buildings, bridges) automobiles (body, springs) aeroplanes (engine, fuselage, landing gear assembly) trains (rails, engine components, body, wheels) shape memory materials magnets

3A Reading: Material Class and Properties (continued)

Materials Class	Definition	Examples	Properties	Applications
Ceramics	Ceramic materials are inorganic materials with non-metallic properties. Ceramics are compounds made of metallic and non-metallic elements and include such compounds as oxides, nitrides, and carbides. The term ceramic comes from the Greek word *keramikos*, which means burnt stuff. The properties of ceramics are normally achieved through a high-temperature heat treatment process called firing.	structural ceramics refractories porcelain glass	lower density than metals strong low ductility (brittle), low thermal conductivity, corrosion resistant high durability	dinnerware figurines vases sinks and bathtubs electrical and thermal insulating devices water and sewage pipes floor and wall tiles dental fillings abrasives, glass television tubes
Polymers	The word polymer means "many parts." A polymer contains many chemically bonded parts or units that are bonded together to form a solid. Two important polymers are plastics and elastomers. Plastics are a large group of organic, man-made compounds based on a polymer of carbon and hydrogen. They are obtained from crude oil. Elastomers are rubbers	**Plastics** nylon polystyrene polyvinyl chloride (PVC) acrylic **Elastomers:** rubber	low density poor conductors of heat and electricity different optical properties usually low densities some soft and flexible, others hard and rigid	fabrics car parts packaging materials bags packing materials (Styrofoam*) fasteners (Velcro*) glue containers, telephone headsets CD cases lunch boxes rubber bands
Composites	Composites are two or more distinct substances that are combined to produce a new material with properties not present in either individual material. Many new combinations include ceramic fibres in metal or polymer matrix.	Fibreglass (glass and a polymer) plywood (layers of wood and glue) concrete (cement and sand)	Lower density than metals strong low ductility (brittle), low thermal conductivity corrosion resistant	golf clubs tennis rackets bicycle frames tyres cars aerospace materials paint

3A Reading: Material Class and Properties (continued)

***Steel**
Steel is probably the most important engineering material. It is an alloy of iron and carbon. There can be between 0.05% and 1.5% carbon added to the iron, depending on the hardness required. This versatile construction material has several very important properties: it is exceptionally strong and can be formed into practical shapes. For example, while an earthquake will shatter the glass in a window, it will probably still leave the steel frame intact.

Sometimes other substances such as chromium or nickel are also added along with the carbon and the product is then known as a steel alloy. Stainless steel is an example of a steel alloy. It consists of iron, carbon and at least 12% chromium.

Ceramics and Dental Use
Dentists have developed a way to use ceramics for fillings despite the special demands on materials to be used inside the mouth. In adapting ceramics for dental use, materials scientists had to develop ceramics that would not be affected by acids, would have low thermal conductivity, would be resistant to wear from chewing, would not expand or contract when exposed to heat or cold, and would be appealing cosmetically.

Semiconductor Materials
There is a small group of materials that are neither good electrical conductors nor good electrical insulators. Instead, their ability to conduct electricity is intermediate. These materials are called semiconductors. Because a semiconductor can conduct electricity under some conditions but not others they provide a good medium for the control of electric current. Silicon is the best known semiconductor as it forms the basis of most integrated circuits.

References
Exploring Materials Engineering, Web site, Chemical and Engineering Department, San Jose State University, www.engr.sjsu.edu/WofMatE.

Materials Science and Engineering, Web site, The Minerals, Metals and Materials Society, www.crc4mse.org/Index.html.

Session 3, Activity B

Materials Applications

In This Session:

Goal

To evaluate properties in order to determine what materials should be used for specific applications.

Outcome

Students apply problem-solving skills to select materials based on their properties.

Description

Using students' materials properties chart from the previous activity, students determine the best materials for a variety of material usage problems.

Supplies

None

Preparation

None

Procedure

Using Materials

1. In groups, students are given materials problems to solve. Each problem involves identifying materials properties, recognizing which materials have these properties, and selecting materials for the product.
2. Each group should solve all the problems and then share and compare their solutions.
3. For each problem, students must determine the following:
4. Which properties are important to solving the problem?
5. Which materials have the important properties?
6. What types of materials would you use to make this product?
7. Students should then make a sketch of the object and label the materials.
8. Groups present their solutions.

3B Materials Applications (continued)

Problems

1. Erin Foods has a problem. Erin started making a new product that requires using hot corn syrup. The corn syrup must be portioned out with a spoon into large bottles while it is still hot (175ºC). The operator will be using a big spoon that she will be holding for more than an hour a day. The company needs a new spoon to serve this purpose. (Important properties: thermal conductivity, density)

2. A new golf club manufacturer would like to make lightweight, sturdy, and electrically non-conductive golf clubs but doesn't know where to start. The golf club heads should be hard and wear resistant and must withstand repeated strokes of high force against the golf ball. (Important properties: electrical conductivity, density, strength, fatigue)

3. Hang Dry Clothespin Manufacturers is undertaking an aggressive campaign to encourage people to conserve energy by hanging their clothes out to dry. They would like to come up with a new modern clothespin that will appeal to the masses. (Important properties: fatigue, ductility)

4. Eircom is trying to come up with a new phone booth for the 21st century. Not only will the phone booth contain pay phones, but will also be a private public place for people to use their cell phones and plug in their laptop computers. The booth must be private, but allow for daylight to pass through and allow people to see if it is occupied. (Important properties: optical)

Wrap Up
Hold a discussion for each problem, comparing the solutions and discussing the benefits and challenges of certain material choices.

Follow With
In *3C: Material Choice,* students consider cost and environmental impact when selecting materials

Materials Applications

Worksheet: Session 3, Activity B

Using the materials properties chart from the previous activity, you will solve each problem to determine the best materials for particular uses.

1. For each problem, determine the following:
   - Which properties are important to solving the problem?
   - Which materials have the important properties?
   - What types of materials would you use to make this product?

2. Make a sketch of the object for each problem and label the materials.

Problems

1. Erin Foods has a problem. Erin started making a new product that requires using hot corn syrup. The corn syrup must be portioned out with a spoon into large bottles while it is still hot (175ºC). The operator will be using a big spoon that she will be holding for more than an hour a day. The company needs a new spoon to serve this purpose.

2. A new golf club manufacturer would like to make lightweight, sturdy, and electrically non-conductive golf clubs but doesn't know where to start. The golf club heads should be hard and wear resistant and must withstand repeated strokes of high force against the golf ball.

3B Worksheet: Materials Applications (continued)

3. Hang Dry Clothespin Manufacturers is undertaking an aggressive campaign to encourage people to conserve energy by hanging their clothes out to dry. They would like to come up with a new modern clothespin that will appeal to the masses.

4. Eircom is trying to come up with a new phone booth for the 21st century. Not only will the phone booth contain pay phones, but will also be a private public place for people to use their cell phones and plug in their laptop computers. The booth must be private, but allow for daylight to pass through and allow people to see if it is occupied.

Session 3, Activity C

Material Choice

In This Session:

A Properties of Materials (80 mins)
- Student Worksheet
- Student Reading (H/W)

B Materials Applications (20 mins)
- Student Worksheet

C Material Choice (20 mins)
- Student Worksheet

D Do Materials Matter? (H/W)
- Student Worksheet

Goal
Students understand factors other than material properties when choosing materials.

Outcome
Students will be able to select material with cost and environmental impact in mind.

Description
This activity introduces students to other factors, aside from material properties, that go into material selection. Using a beverage container, students compare the cost of making a beverage container from different materials in order to understand the economic tradeoffs when choosing materials. Environmental impact is introduced to students as they design a container that can be reconstituted to make another product or reused for a secondary purpose.

Supplies
1 of each for each group: Plastic, aluminium, and glass beverage containers

Preparation
Distribute a 330ml plastic, aluminium, and glass beverage container to each group.

Procedure

Materials and Cost

1. Begin a discussion of cost. Explain that cost is often one of the most important design considerations when choosing materials. In most designs the aim is to minimize the cost. For most products material cost dominates design. This makes it difficult to introduce expensive, high performance materials. Cost only becomes less important when product performance is everything to the customer and they are prepared to pay for it. Examples are top-of-the-line sports products (racing bicycles, sports cars, golf clubs etc.), medical implants (hip prostheses and heart valves). In some cases cost is virtually irrelevant, for example in satellites

2. Introduce beverage containers. Beverage containers pose an interesting engineering challenge. They must satisfy a number of physical and structural criteria, must be inexpensive, and should have a minimal impact on the environment.

3C: Material Choice (continued)

3. Introduce the challenge: Your class has decided to go into the fruit juice business. You have already come up with delicious recipes and are now considering how you will package the drinks. As employees, the owner (the facilitator) has asked for your input on which type of beverage container to use. You are to do a cost analysis of aluminium, plastic, and glass and make a case for one of these materials.

Cost Analysis of Beverage Containers

1. Explain that many cost factors go into determining what type of material to use for a product. Tell each group to analyze the charts and determine which type of material they feel is best for packaging the fruit juice. They should prepare an argument to support their position.

2. The first chart shows the number of containers per kg of material, the raw material cost per kg, the production cost per container, and the average shipping cost per kg. Using this information, students rank aluminium, glass, and plastic in the total cost to produce and deliver one container. (*They will need to figure out how much one container weighs for each material, the material cost for one container, and the shipping cost for one container. Plastic is the cheapest, followed by aluminium, and then glass*)

Material	**# containers /kg**	**Material Cost in €/kg**	**Production €/container**	**Shipping €/kg**
Aluminium	30	.70	.10	.50
Glass	2	03	.06	.50
Plastic	15	.50	.04	.50

3. The next chart shows the total cost of returning the material to a state where it can reused to make a new container instead of using raw materials. This includes the market price to purchase and reprocess scrap material. Note that this processing includes cleaning the material, shredding or grinding, and re-melting. The chart also includes the cost of disposing the material into a landfill as an alternative to recycling. Students calculate the cost to purchase scrap material and reprocess it and compare this amount to the cost of the raw material (in the above chart.) For each material, is it more economically advantageous to recycle scrap material or dispose of it in a landfill? (It makes sense to recycle aluminium and glass, but it is cheaper to dispose of plastic.)

3C: Material Choice (continued)

Material	Scrap €/kg	Process Scrap €/kg	Disposal €/kg
Aluminium	.35	.15	.02
Glass	.01	.01	.02
Plastic	.10	.50	.02

4. Global warming has been linked to the increase in emissions to the atmosphere of carbon dioxide. Carbon dioxide is emitted by the burning of fossil fuels. Fossil fuels are burned to create energy that is used to manufacture and transport materials. Manufacturing beverage containers using recycled materials decreases the total carbon dioxide emissions because reprocessing consumes less energy than processing the raw material. The following chart summarizes the kilograms of carbon dioxide emissions avoided by using recycled materials. From which material do you gain the most benefit by recycling? *(Aluminium, plastic, glass)*

Material	kgs of CO_2 avoided per kg of material recycled
Aluminium	4.5
Glass	0.2
Plastic	0.8

Make a Case

1. Now that each group has done a cost benefits analysis of three different types of beverage containers, have each group prepare an argument to lobby to the head of the beverage company to use plastic, glass, or aluminium beverage containers. Groups may also consider other factors aside from cost, such as materials properties, taste, and aesthetics.

2. Hold a debate to convince the company owner (i.e. the facilitator) how he or she should package the new beverage.

3. Discuss the tradeoffs between economic decision-making and total cost decision-making which incorporates environmental benefits.

3C: Material Choice (continued)

Container Design: Extending the Life

1. Now that each group has chosen which material they think makes the most sense from a cost perspective, they now consider how the life of the beverage container can be extended by coming up with a secondary use for the container.

2. Present the following design challenge: You have been asked to design a beverage container that would not be considered waste after its use. Consider how the container might be recycled and reconstituted for another use or how the container might be redesigned to achieve a secondary use.

3. Provide a few examples of this to get students to think innovatively.

   Emium (Argentina, container company): Emium redesigned the shape of a bottle so that it could be a building block that can be attached to others to fulfill a wide range of recreational or functional structures. The bottles can be attached to one another lengthways or sideways by pressing the protruding knobs of one into the cavities of the other. The scope of use for these include: children's toys or play houses, furniture, shelving, boxes, partitions. http://www.emium.com.ar/ingl/home.html

   Patagonia (United States, outdoor apparel): Patagonia became the first company to adopt a post-consumer recycled fleece into their product line. These are manufactured from PET soft drink bottles. From 3,700 recycled 2-litre plastic soft-drink bottles, 150 fleeces can be manufactured. This saves a barrel of oil and avoids approximately half a ton of toxic air emissions being released into the atmosphere. http://www.patagonia.com/

4. Groups should sketch their idea and present their designs.

Wrap Up
Students share their designs. As an optional extension (to be done at home), they can create models of their designs.

Material Choice

Worksheet: Session 3, Activity C

Did you know that when you purchase a beverage, you pay more for the packaging than the beverage itself? So, what does it take to produce a beverage container and how are decisions made about what type of container to use?

The challenge: Your class has decided to go into the fruit juice business. You have already come up with delicious recipes and are now considering how you will package the drinks. As employees, the owner has asked for your input on which type of beverage container to use. You are to do a cost analysis of aluminium, plastic, and glass and make a case for one of these materials.

This chart shows the number of containers per kg of material, the raw material cost per kg, the production cost per container, and the average shipping cost per kg. Using this information, rank aluminium, glass, and plastic in the total cost to produce and deliver one container. You will need to first determine how much one container weighs

Material	# containers /kg	Material Cost in €/kg	Production €/container	Shipping Cost in €/kg
Aluminium	30	.70	.10	.50
Glass	2	03	.06	.50
Plastic	15	.50	.04	.50

The next chart shows the total cost of returning the material to a state where it can reused to make a new container instead of using raw materials. The chart also includes the cost of disposing the material into a landfill as an alternative to recycling. Calculate the cost to purchase scrap material and reprocess it and compare this amount to the cost of the raw material (in the above chart.) For each material, is it more economically advantageous to recycle scrap material or dispose of it in a landfill?

Material	Scrap €/kg	Process Scrap €/kg	Disposal €/kg
Aluminium	.35	.15	.02
Glass	.01	.01	.02
Plastic	.10	.50	.02

3C Worksheet: Material Choice (continued)

Global warming has been linked to the increase in emissions to the atmosphere of carbon dioxide. Carbon dioxide is emitted by the burning of fossil fuels. Fossil fuels are burned to create energy that is used to manufacture and transport materials. Manufacturing beverage containers using recycled materials decreases the total carbon dioxide emissions because reprocessing consumes less energy than processing the raw material. The following chart summarizes the kilograms of carbon dioxide emissions avoided by using recycled materials. From which material do you gain the most benefit by recycling?

Material	kgs of CO_2 avoided per kg of material recycled
Aluminium	4.5
Glass	0.2
Plastic	0.8

What type of beverage container do you think the juice company should use? Make a case for aluminium, glass, or plastic.

Extending the Life of the Container

Design challenge: You have been asked to design a beverage container that would not be considered waste after its use. Consider how the container might be recycled and reconstituted for another use or how the container might be redesigned to achieve a secondary use. Be innovative! Sketch your design idea.

Session 3, Homework

Do Materials Matter?

In This Session:

Goal

To look at common objects and determine whether their materials make a difference in function and effectiveness.

Outcome

Gain an understanding of the connections between materials and function.

Description

Students walk through their homes looking at objects and analyzing what materials were used to make them.

Procedures

1. Explain that the young engineers will walk through their home like a detective, looking for objects and what they are made of, and why the materials matter. Ask students to bear in mind all the different properties they have discussed during the session.

2. When looking at materials, they should consider what the product property requirements are and why those materials were selected. Provide a few examples such as: An outdoor mat may need to be waterproof and non-slip, thus rubber is often used.

3. Ask them to consider the flooring in their home. Do they have different flooring in different rooms? Why? Consider how soft carpet materials, vinyl, and wood flooring serve different purposes based on functional needs.

Next Class

Share and compare observations, discussing how and why particular materials are used.

Materials Scavenger Hunt

3D Worksheet: Homework

Walk through your home like a detective. Look for objects and what they are made of. Write a sentence about each item you find where the materials it is made of matter!

What is it?

What does it do?

How and why do the materials matter?

What is it?

What does it do?

How and why do the materials matter?

3D Worksheet: Materials Scavenger Hunt (continued)

What is it?

What does it do?

How and why do the materials matter?

What is it?

What does it do?

How and why do the materials matter?

Think about the end-of-year projects you are considering. What material property requirements might your project have?

Notes:

Engineering Fundamentals

Session 4

Electronic Engineering I

In This Session:

- **A Building Simple Circuits (40 mins)**
- **B Using Simple Switches (40 mins)**
- **C Using a 'Silicon Chip' (30 mins)**
- **D Completing the Input Pattern for the 4093 (10 mins)**

Background information for teachers on electronics can be found in the Teacher's Notes section at the end of the Teacher Guide. As the electronics activities are quite sophisticated all of the normal text in Sessions 4 and 5 has been duplicated in the Student Booklet as a guide for students. Any text in italics is in the Teacher Guide only. Students should study their Student Booklet prior to commencing the practical work contained in the activities.

Have you ever wondered how burglar alarms work, or how street lights turn on automatically when it gets dark? Or perhaps you have seen Christmas tree lights that twinkle, turning on and off every few seconds. In this module you will find out how to build electric circuits to do these sorts of things. You will be using some modern pieces of electrical equipment that have 'silicon chips' inside them. They can be easily damaged, so take care of them! While you do the work in this module, try to think of ways you could use the circuits you build in a project of your own. Most of the time you will be working with small pieces of electrical equipment that you put onto a circuit board, using a battery to make them work. However, before you begin there is a number of key ideas that you need to know. (Most of them you may have met in your Junior Certificate work in Science or Technology.)

Safety

You should know that electricity can be dangerous. If too much current flows through you, it can kill. This can happen if you use electricity from the mains electricity supply. In this module you do not need to use the mains supply at all. However, your teacher may ask you to use a powerpack that is connected to the mains. You must use the powerpack ONLY in the way that your teacher tells you. DO NOT change any of the controls 'just to see what happens'. You could damage the apparatus you use; but more importantly, you could harm yourself or other students in your group.

Intel Education

4: Electronic Engineering I (continued)

Key ideas in electricity

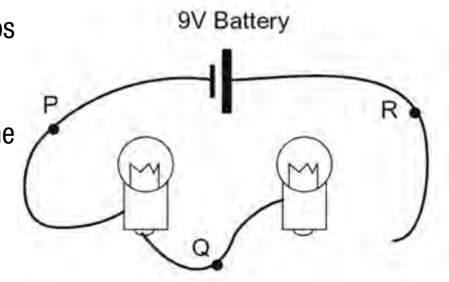
1. Electricity needs a complete circuit to make things work.
2. The movement of electricity round a circuit is called an electric current (or just current for short).
3. To make current move round a circuit there has to be a battery or powerpack that supplies a voltage. You will be using a 'nine volt' (9V) battery.
4. A battery has a positive terminal marked with a + sign. It also has a negative terminal, marked with a – sign. We say that current flows from the positive terminal to the negative terminal.
5. The general rule is that the greater the voltage applied to a circuit, the more current will flow.
6. Current goes through devices in a circuit, e.g. lamps, motors, buzzers; but voltage is measured across each of the devices.
7. Metals allow current to flow through them very easily. We say metals conduct electricity easily. They have a low resistance. If a substance does not conduct electricity at all easily we say it has a high resistance. If a substance has a very, very high resistance we usually call it an insulator. Plastic, rubber and wood are insulators.
8. Some substances are neither good nor bad conductors; they suddenly change their ability to conduct as the voltage changes. These substances are known as semiconductors. Often they contain the element called silicon.

A word of warning: people often talk about 'the power' in a circuit, or a battery. In nearly every case, using the word power when talking about electric circuits is likely to be wrong. So, please forget about 'power'—if you are tempted to explain how a circuit works by talking about power, our advice is: don't!

Check your understanding

Here are a few questions for you to do in your group. Discuss the questions with your partner(s) and decide on your answers together. This should take you no more than 10 minutes. Your teacher will check your answers when you have finished.

Q.1 The diagram show a battery and lamps connected with some wires.
(i) Why won't the bulbs light?
(ii) What would you do to make the circuit work properly?
(You can draw on the diagram if you want.)



A.1 *(i) Circuit not complete;*
(ii) Link wire and bulb.

4: Electronic Engineering I (continued)

Q.2 We measure the amount of current flowing through a circuit in amps (A). Suppose the circuit is made to work properly so that both bulbs light. Also suppose we measured the current flowing through the wire at P as one amp (1A).
(i) What would you predict the size of the current to be at point Q?
(ii) What would you predict the size of the current to be at point R?

A.2 (i) *Correct predictions are 1A at all three places.*
(ii) *Current is not 'used up' in a circuit! (Many students believe it is.)*

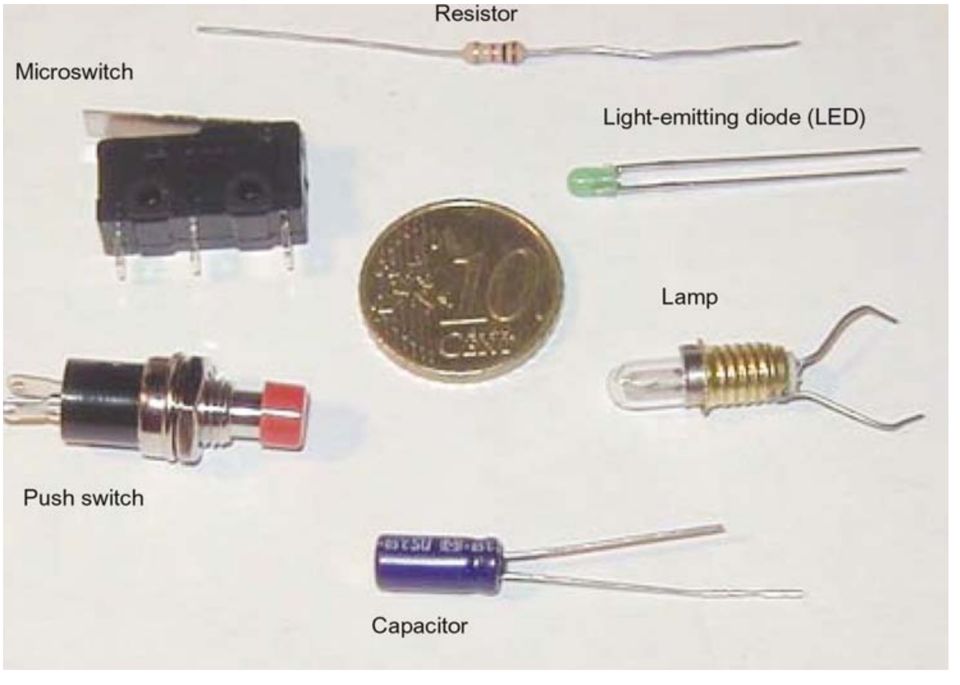
Q.3 Assume you had built the circuit so that both bulbs were glowing. What do you think would happen if you connected a wire from point P to point Q?

A.3 *The bulb would 'go out'. The wire from P to Q would have a much lower resistance than the bulb, so almost all the current would go through the wire and not the bulb. Incidentally, the other bulb would glow much more brightly.*

Q.4 Imagine that the circuit was working properly, with both lamps glowing. Now imagine you replaced the 9V battery by a 90V battery. Write down what you think would happen, and why it would happen.

A.4 *The 90V battery could drive a much greater current through the circuit (about 10 times as much). It is likely that so much current would 'burn out' the filaments of the bulbs; i.e. they would glow very brightly for a brief moment and then stop working.*

You are going to use small electrical components. You can see pictures of some them below.



4: Electronic Engineering I (continued)

Supplies
For Each Pair Of Students

- 1 x Breadboard
- 1 x 9V battery (PP3)
- 1 x clip for battery
- 2 x 4093B CMOS chip
- 2 x 2003A Darlington Driver chip
- 2 x Small 3V lamp
- 2 x Lamp holder
- 2 x Resistors, 1K, 10K, 22k, 47k (each)
- 2 x Capacitors, 10mF, 22mF, 47mF, 100mF (each)
- 1 x Push switch
- 1 x Micro switch
- 1 x Buzzer
- 8 x Selection of wires—best purchased as a kit that should supply enough for all groups.

Shortly, you will build a circuit using the lamps and LEDs. Because the components are small, we need a special way to build circuits with them. We use a 'bread board'.

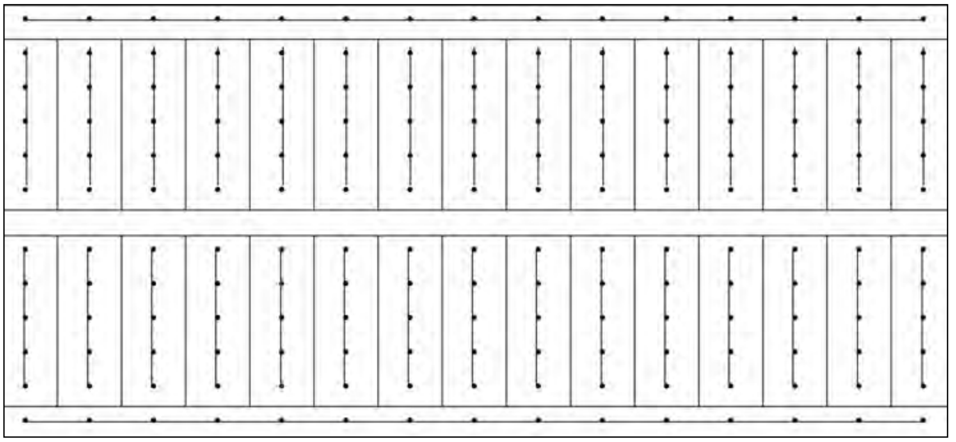
Below is a picture of part of one in use. It is vital that you understand how bread boards are made. They can be confusing at first because they have so many 'holes' where the components can fit, and because the connections between the holes are hidden under the plastic. The bread board you use may not look exactly like the one in the photo, but it will work in exactly the same way. Here are the key things you need to know:

- The bread board has four main parts:
- One or more horizontal rows of holes at the top. All these holes are connected together by a wire running underneath.
- One or more horizontal rows of holes at the bottom. These holes are also connected together.
- Two sets of five rows of holes separated by a gap. These holes are connected vertically only. So, for example, two holes side-by-side are NOT connected. The columns are not connected across the gap.

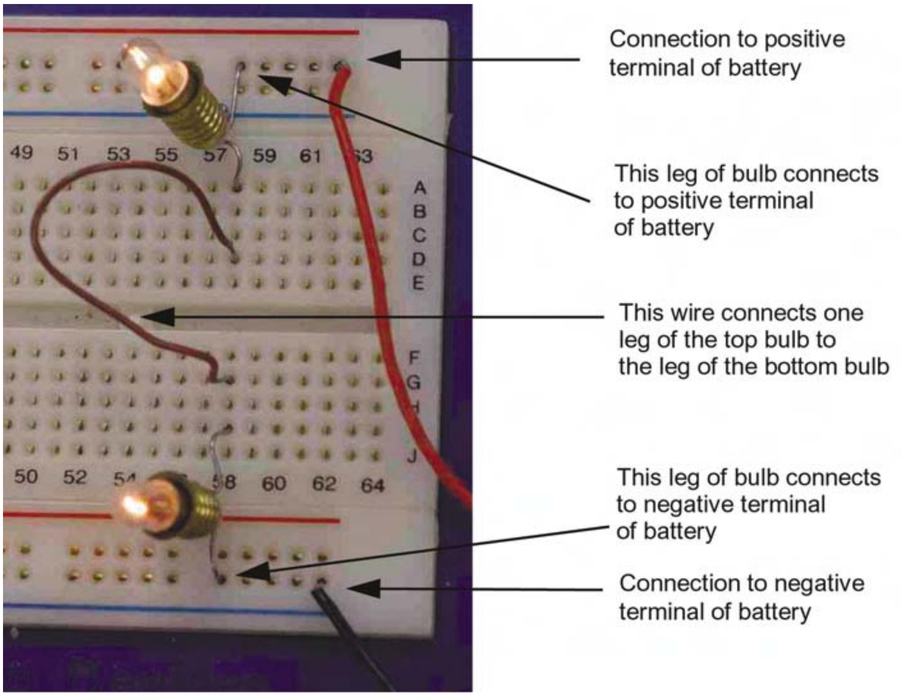
Look carefully at the photo of the bread board in use and the diagram showing the way the holes on a bread board are connected. Make sure you can understand why the components and wires are connected the way they are shown.

4: Electronic Engineering I (continued)

Diagram showing the connections on a bread board



Picture of a bread board in use



Electronic Engineering I

Key Concepts: Session 4

The main aims of this section of Design & Discovery are to give students and enjoyable practical experience of building circuits that:

(i) allow them to develop insights into some uses of modern integrated circuits, and
(ii) give them ideas for how they might use simple circuits as part of their final projects.

Throughout the emphasis should be on students working in groups and sharing their ideas, with the emphasis on observing what happens during the practical tasks that they undertake.

Very little theory is needed to perform the tasks successfully. The Teachers' Notes (see resource section) give some of the theory, but it is not intended that students should know, for example, how semiconductors are used in the manufacture of 'silicon chips'. On the other hand, it is important to stress the correct use of basic terms such as 'current', 'voltage' and 'resistance'.

Key concepts

The work begins with a brief revision of key ideas in electricity that most students should have met in Junior Certificate Science; especially:

(i) a complete circuit is needed for an electric current to flow;
(ii) a resistor will make the flow of current round a circuit more difficult;
(iii) the voltage of a battery or power pack is a measure of the 'push' that can make a current flow.

Additional ideas that are developed include:

(iv) current is not used up when it flows through a circuit;
(v) not all electrical component obey Ohm's law, e.g. silicon chips, capacitors, light emitting diodes (LEDs);
(vi) circuits inside silicon chips can be turned on or off by changing the voltage they sense (rather than current).

It is not expected that students will master such ideas. However, this should not prevent them from being able to observe the effects of operating their circuits. Thus, at the end of this unit of work they should be able to:

(i) know how to use switches that normally open and/or normally closed connections;
(ii) know uses for reed switches.
(iii) use a logic gate to detect changes in the states of switches attached to the gate inputs;
(iv) use the output of a logic gate to switch on (or off) an LED or buzzer;
(v) suggest uses for such circuits;

Key Concepts (continued)

If students progress rapidly through the core work, their are suggestions for further practicals that they can undertake. These involve them in building circuits that can be used

(i) as timing circuits, e.g. to make LEDs flash on and off, and
(ii) to control motors.

Throughout this section, students should be encouraged to think of applications for the circuits they build, and how they might form part of their final project.

Session 4, Activity A

Building Simple Circuits

In This Session:

A Building Simple Circuits (40 mins)

B Using Simple Switches (40 mins)

C Using a 'Silicon Chip' (30 mins)

D Completing the Input Pattern for the 4093 (10 mins)

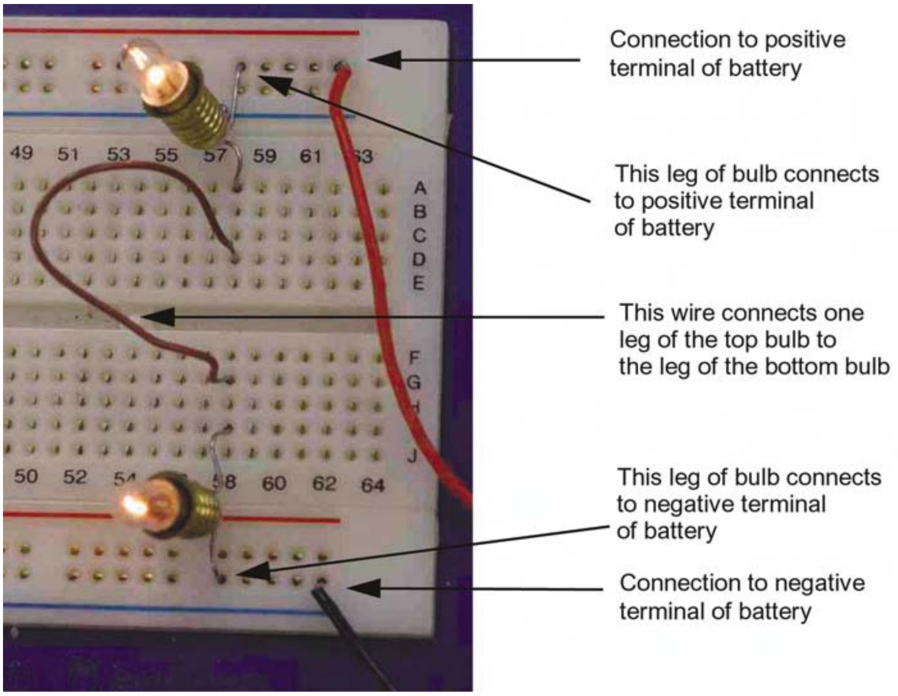
Goal
Get familiar with using breadboards to build simple circuits

Outcome
Participants will be able to use a breadboard to light lamps and use LEDs in a circuit.

Description
Students build a circuit to make 2 lamps light then replace one lamp with an LED.

Supplies
Breadboard, electrical wire, 2 lamps, 1 LED

Procedure
1. Build the circuit shown in the photo to make two lamps light.



4A: Building Simple Circuits (continued)

Notes:
When you do this, hold the legs of the bulb holders near the bottom, not at the top near the holder itself. That way you will find it easier to put the legs into the holes. You may find it difficult at first to get the legs and/or wires into the holes. Keep trying: often the connectors in the holes are stiff at first. If it really is impossible, try a different set of holes. The last thing to connect into the circuit is the battery.

2. Investigating LEDs
   (i) First, look at the picture of an LED. It has two legs, one shorter than the other. The longer leg is called the anode; the shorter is the cathode. When you pick up an LED, if you look carefully you will find there is a small flat portion on the coloured barrel; this also marks the cathode.

   (ii) Remove the bottom lamp on the bread board. Try replacing it with an LED. Note where you have put the anode and cathode legs. Does the LED light up? Try changing the LED round so that the anode goes where the cathode went (and vice versa). What happens now?

A. *(ii) the LED will only light up when the cathode is connected through the circuit to the negative terminal of the battery*

   (iii) Now make the circuit work with two LEDs and no lamps.

   (iv) Which is the general rule that LEDs obey? (a) The cathode must eventually connect to the positive ‘end’ of a circuit, or (b) the cathode must eventually connect to the negative ‘end’ of a circuit?

A. *(iv) (b) is correct.*

4A: Building Simple Circuits (continued)

Follow-up work

1. Find out where LEDs are used in your home. Write down a list of two or three uses.

A. *Used in remote controls for hi-fi, tvs etc.*

2. Use the internet or a library to find out why LEDs are so often used instead of ordinary lamps. Bring your findings to the next lesson.

A. *LEDs generally require less current to make them work than do ordinary filament lamps. Thus they will not 'run down' a battery as fast as filament lamps. Also, they tend to be very long-lasting and not so susceptible to failure if they are moved.*

3. Write down one or two ways in which you could use LEDs in a project. E.g. in toy, or model. Are there things that you would like to make LEDs do that they do not do in the circuit you built?

A. *LEDs could be used as miniature lamps in a model home, or car etc. It is possible to 'string them together' to make Xmas tree lights. Students might want to make them flash. There is an optional practical about this. However, you might like to know that it is possible to buy LEDs that will flash on their own accord; but the flashing rate is fixed. Also, it is possible to buy LEDs of different colours; especially red, blue, green, yellow, and even some that give out white light.*

Session 4, Activity B

Using Simple Switches

In This Session:

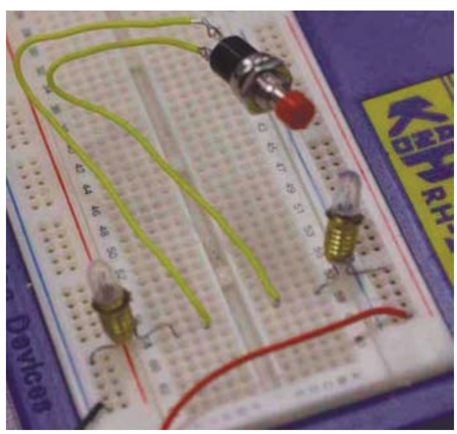
Goal
Investigate how a switch works.

Outcome
Students will be able to connect switches into a circuit and explain how they work.

Description
Students connect a push switch and a micro switch into the circuit from Activity 1 and investigate their differences.

Supplies
Breadboard, electrical wire, 2 lamps, 1 LED, 1 push switch and 1 micro switch

Procedure
1. Try connecting the push switch as shown in the photo below.



2. Does it matter which way round the switch is put into the circuit? (Try it.)

A. *No.*

3. Explain what the switch does. For example, does it behave like a light switch at home, that locks into place when it is pressed, or does it only work when you hold the button down, or…?

A. *It only works when the button is pressed. That is, it doesn't latch (like most home light switches).*

4B: Using Simple Switches (continued)

4. Now connect the micro switch. When you use the micro switch, make sure you use the labels as shown, i.e. with the lever pointing to the right.It has a lever that is very sensitive—a slight push on the lever, and the switch will work. However, you can see that it has three terminals (and three wires attached).

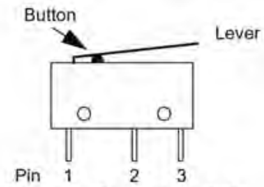
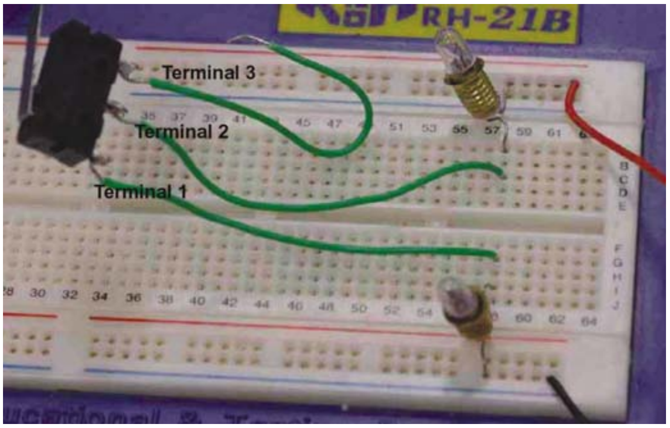


Diagram of a micro switch



Your task is to investigate how this switch works. Try using two of the three wires in turn to put the switch in the same circuit as you have just used. Carefully note down which two leads you use each time, and what happens before and after the lever is pressed: Call the wires 1, 2 and 3 as shown in the diagram above.

Wires used	What happens to the lamps *before* the lever is pressed?	What happens to the lamps *after* the lever is pressed?
1 and 2	*Light off*	*Light on*
1 and 3	*Light on*	*Light off*
2 and 3	*Light off*	*Light off*

5. One set of contacts in the micro switch is known as 'normally open (NO)'. another set is said to be 'normally closed (NC)'. Which pins make the NO contacts, and which pins make the NC contacts?

A. *Pins 1 and 2 are NO; pins 1 and 3 are NC.*

In this part of the work, there is nothing more for the students to do than get the circuit working. Observations and results should be recorded in their design notebooks.

4B: Using Simple Switches (continued)

Follow-up

1. Which switch is the most sensitive? What do you think is the point of having a lever on the micro switch?

A. *Hard to say just using one's hands; but the micro switch is the more sensitive in practice because the lever can be used to 'magnify' small movements that would not affect the push switch. (The button on the latter has to move much further than the lever on the micro switch.)*

2. Briefly describe two applications that would make use of the 'ordinary' switch, and two for the microswitch. The examples you use could be ones that you might use in a project, or an application in industry; e.g. for controlling machines.

A. *A suitable push switch could be used to work a camera or flash light, or other application where only a momentary signal, light etc. is needed. A variety of push switch is used to control pieces of equipment such as electric mowers or drills where it is important that the device stops if the handle/trigger is released.*
The micro switch would be used where it necessary to start/stop equipment automatically; e.g. good passing down a conveyor belt could be made to touch a micro switch that is connected to an electronic counter. Another example, might be where an alarm is made to sound at the slightest opening of a door/window to which the micro switch is attached.

Session 4, Activity C

Using a 'Silicon Chip'

In This Session:

Goal
Investigate the use of a 'Silicon Chip'

Outcome
Students will be able to use a silicon chip as part of a simple circuit.

Description
Students build a circuit consisting of a silicon chip and and an LED and investigate the effect of the silicon chip when the circuit is broken.

Supplies
1 Breadboard, some electrical wire, 1 *4093* silicon chip, 1 LED.

Procedure
Almost everything we use in the home or at work now makes use of microelectronic circuits. In this lesson you are going to investigate the use of one type of 'chip' called a logic gate. The silicon chip itself that makes the device work is hidden inside the body made of insulating material. The chip you use has fourteen legs (often called 'pins') that we use to make the connections to the silicon chip inside. It is known by its number; in this case it is a 4093.

1. Look carefully at the 4093. At one end you should see a small semi-circle or notch marked at one end. You will use this to tell you which way round to put the chip in a circuit. The pins (legs) are numbered from one to fourteen as shown in the diagram. Pin number 14 connects to the positive terminal of the battery, and pin number 7 goes to the negative terminal. You will only use pins 1, 2 and 3 (as well as 7 and 14) in your circuits. Pins 1 and 2 are inputs, pin 3 is the output.

2. The circuit you are going to build is shown in the photo below.

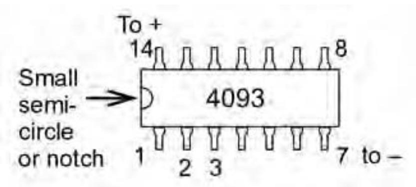
Before you start, please not that It is vital that you put the chip the right way round in the circuits you build. (Make sure you can identify the end with the semi-circle or notch.) If the chip has not been used before you will find that the legs do not quite fit in the holes correctly. You will have to gently bend them inwards by a very small amount. Ask your teacher for advice before doing this. Make the circuit as shown in the photo. The battery should only be connected when everything else is in place. The LED should light up. If it doesn't, carefully check all the connections are made to the right places, and that the wires are properly seated in the holes.

intel Education

4C: Using a 'Silicon Chip' (continued)

3. Try removing the LED and replacing it by a buzzer.

At this stage you might wonder what the point of this circuit is—after all there are simpler ways of making an LED light. Well, the idea is that this chip can do something that ordinary circuits can't do. Especially, it can make something happen when a circuit is broken. (You may recall that up until now you we expect devices in a circuit to turn off if a circuit is broken.) To see how the chip behaves you will have to investigate its properties more closely.



We shall use a short-hand to draw up a table of results. Here are the rules:

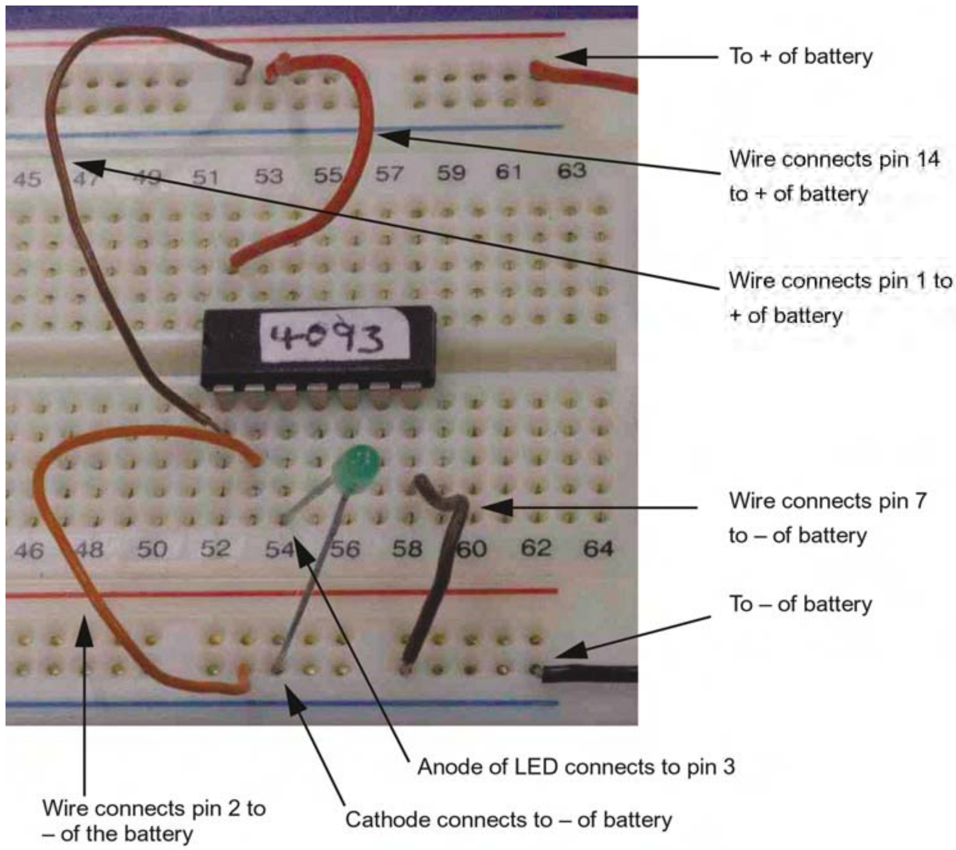
If a pin is connected to the + of the battery, we shall say that the pin is 'ON'.

If a pin is connected to the – of the battery, we shall say that the pin is 'OFF'.

If the output pin (3) is live, i.e. LED turns on, it is 'ON'; if the LED is off, the pin is 'OFF'. For example, if you look at your circuit you just made, the pattern is this:

	Pin 1	Pin 2	Pin 3
	Connected to +	Connected to –	Live (turns LED on)
Code	ON	OFF	ON

4C: Using a 'Silicon Chip' (continued)



Session 4, Activity D

Completing the Input Pattern for the 4093

In This Session:

A Building Simple Circuits (40 mins)

B Using Simple Switches (40 mins)

C Using a 'Silicon Chip' (30 mins)

D Completing the Input Pattern for the 4093 (10 mins)

Goal
To investigate further the properties of the 4093

Outcome
Students investigate how changing the pin input can affect the pin output.

Description
Students vary the inputs on the pins of the 4093 and record the outputs in a table.

Supplies
1 Breadboard, some electrical wire, 1 4093 silicon chip, 1 LED.

Procedure

Use the same circuit as in the last practical to complete the table of results below.

Note that you canmake the input to a pin ON by connecting it to the + of the battery, and 'OFF' by connecting it to the – of
the battery.

Pin 1	Pin 2	Pin 3 (output)
OFF	*OFF*	*ON*
ON	*OFF*	*ON*
OFF	*ON*	*ON*
ON	*ON*	*OFF*

Students should populate the table in their Booklet and the teacher can check when completed.

intel Education

Notes:

Session 5

Electronic Engineering II

In This Session:

- **A** **A Reed Switch Circuit (40 mins)**
- **B** **Making an LED Flash (40 mins)**
- **C** **Controlling a Motor (40 mins)**

Background information for teachers on electronics can be found in the Teacher's Notes section at the end of the Teacher Guide. As the electronics activities are quite sophisticated all of the normal text in Sessions 4 and 5 has been duplicated in the Student Booklet as a guide for students. Any text in italics is in the Teacher Guide only. Students should study their Student Booklet prior to commencing the practical work contained in the activities.

Supplies

For Each Pair Of Students

- 1 x Breadboard
- 1 x 9V battery (PP3)
- 1 x clip for battery
- 2 x 4093B CMOS chip
- 2 x 2003A Darlington Driver chip
- 2 x Small 3V lamp
- 2 x Lamp holder
- 2 x Resistors, 1K, 10K, 22k, 47k (each)
- 2 x Capacitors, 10mF, 22mF, 47mF, 100mF (each)
- 2 x LEDs, red, green (each)
- 1 x Motor
- 1 x Reed switch and magnet (sold as pair)
- 1 x Push switch
- 1 x Micro switch
- 1 x Buzzer
- 8 x Selection of wires—best purchased as a kit that should supply enough for all groups.

intel Education

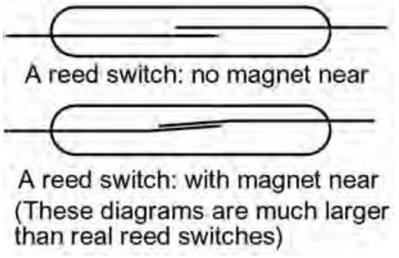
Session 5, Activity A

A Reed Switch Circuit

In This Session:

Reed Switches

The pattern you should have discovered tells you that when one (or both) of the inputs is connected to the positive of the battery the output is OFF; otherwise the output is ON. Now imagine that you have the job of designing a burglar alarm which turns on if the front or back door in a house is opened. We could do this if we find a way of wiring the doors to make a complete circuit to a battery and a 4093 chip. Here is one way of doing this; but first you need to know something about devices that are used in real burglar alarm systems. They are called reed switches, and are operated by magnets.



A reed switch has two thin pieces of metal that are contained in a small glass tube which has had all the air removed. When a magnet is brought near to the glass, the two metal contacts are attracted together, and the contacts are connected.

Your teacher will show you a reed switch, but they are too fragile to be used without being held in a protecting plastic case. You will use a reed switch and magnet that can be used as part of a real burglar alarm system.

5A: A Reed Switch Circuit (continued)

Goal
To become familiar with how a reed switch operates and how they might be used in everyday life.

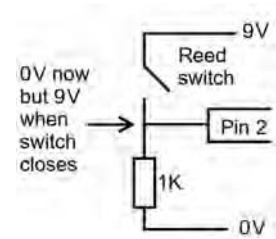
Outcome
Students will be able to build a reed switch circuit and understand how they might be used in a burglar alarm system.

Description
Students add a reed switch to the circuit they built in Session 4, then swap the LED for a buzzer.

Supplies
As in Session 4 plus a reed switch.

Procedure
1. Build the circuit shown in the photo below.
   (i) What happens when you bring the magnet near to the reed switch?

A. *(i) The LED goes out. Note that this is how reed switches in burglar alarm systems work: themagnet may be on a window, and the reed switch on the frame. When the widow is closed, the alarm will be off; but when the window opens the alarm sounds. Of course, real alarm systems are more complex than this would suggest; but the principle remains valid.*



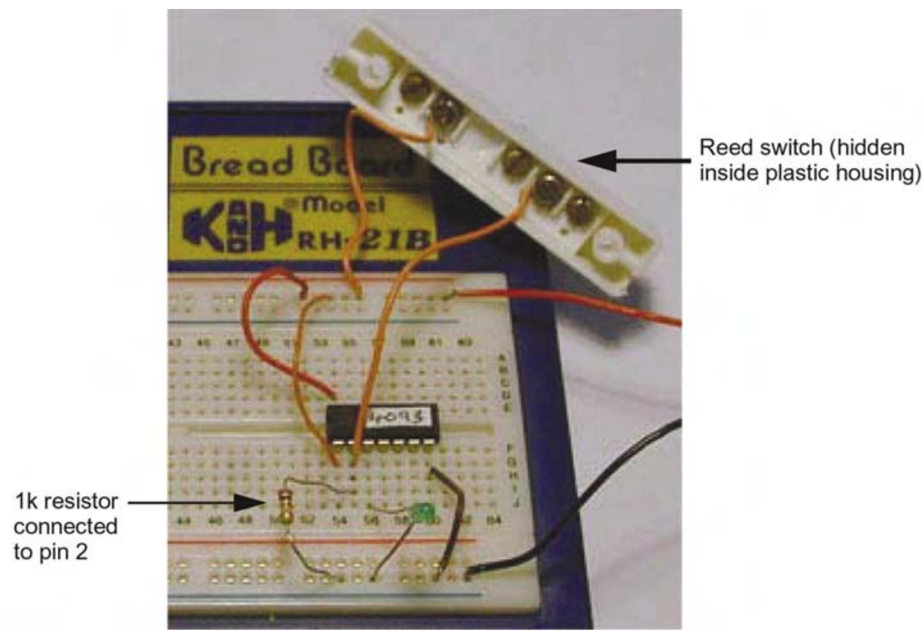
You may be asked why the resistor is needed in the circuit. Here is the answer: Logic gates only work properly if their inputs are either 'high' or 'low'. If they are left unconnected the chip doesn't know what the input levels are. The resistor connects pin 2 to 0V (the negative terminal of the battery), so if the reed switch is open, the (partial) circuit looks like this: As shown, pin2 is 'low'; but when the switch is closed, pin 2 is connected to 9V, i.e. it goes 'high'. If the resistor is omitted, (so there is no connection to 0V) when theswitch is open, pin 2 is neither 'high' nor 'low', and the circuit will be unstable.

2. Swap the LED for a buzzer.
   Students like noise!

5A: A Reed Switch Circuit (continued)

3. How would you change the circuit so that it uses two reed switches.
   (i) See if you can find two ways of doing this. What are the advantages/disadvantages/uses of the two ways if you were to use them in a real burglar alarm?
   (ii) How could you make use of them in a real burglar alarm system?

A. *(i), (ii) The two reed switches could be put in series with one another. A more sophisticated method is to duplicate the reed switch and resistor combination (shown connected to pin 2 of the chip) and putting the second switch and resistor on pin 1. In real burglar alarms systems it is common to have the sensors allocated to different zones. If the switches are in series they must be in the same zone. If they are on different circuits, they can be isolated from one another and allocated to separate zones.*



To follow-up

1. The reed switch and magnet are made of white plastic. Why do you think this might be? (That is, why white, and why plastic?)

A. *Cosmetic reasons. Least offence to use in a home. Plastic an insulator, easily moulded and inexpensive.*

2. Think about how you would put the switch and magnet to use in your home on a door or window. Where would the switch go, and where would the magnet go?

A. *At first sight it might not seem to matter which goes on the door/window and which on the surround; but in practice, the wires go to the reed switch and not the magnet. So the magnet goes on the door/window, and the switch on the surround.*

5A: A Reed Switch Circuit (continued)

3. Are these devices suitable for all types of door and window? How could you change the design to be suitable in other cases?

A. *Not easy to use with metal doors/windows; rather than using screws, need an alternative means of fastening. (Could be glued on of course.) Also, the switch and magnet are quite large. it would be better to have smaller versions, e.g. that could be inserted into the structure of the door/ window and surround. This keeps them out of sight. Such devices are available.*

4. Think how you might make a reed switch and magnet combination that could be hidden from view. Sketch your design, and write a brief explanation.

A. Any sensible solution.

5. In industry it can be important to prevent something happening if a circuit is left unconnected; i.e. left 'open'. Think of examples, e.g. a safety guard for a machine that prevent the machine form starting if the guard is not down. (Why could this be a vital safety device?) How could you adapt your circuit to act as part of such a safety system?

   See comments in "To Follow-Up"

Session 5, Activity B

Making an LED Flash

In This Session:

Flashing LEDs

There is a neat trick that can be played on a 4093 chip to make it repeatedly flash an LED on an off. To make it do this, you need to use a capacitor and a resistor (see the photo on page 109).

A capacitor stores electric charge. It has two ‘legs’, and like an LED one must be connected (eventually) to the positive and one to the negative terminal of a battery. You will find a + sign on the body of the capacitor near one of the legs. The larger the value of the capacitor the more charge it can store. We measure a capacitor’s ability to store charge by the value of its capacitance, measured in units of farads. A one farad (1F) capacitor can store a large amount of charge, and it is more common to use much smaller values in electronic circuits. You will use a value of 10 or 100 micro-farads (10 μF or 100 μF) . (One micro-farad is one millionth of a farad.)

A resistor can help to control how much current flows through a circuit. A very high resistance would be one hundred million ohms, 100M Ω. However, you will use a resistor of value between 1 thousand (1k Ω) and 47 thousand ohms, 47k Ω.

Intel Education

5B: Making an LED Flash (continued)

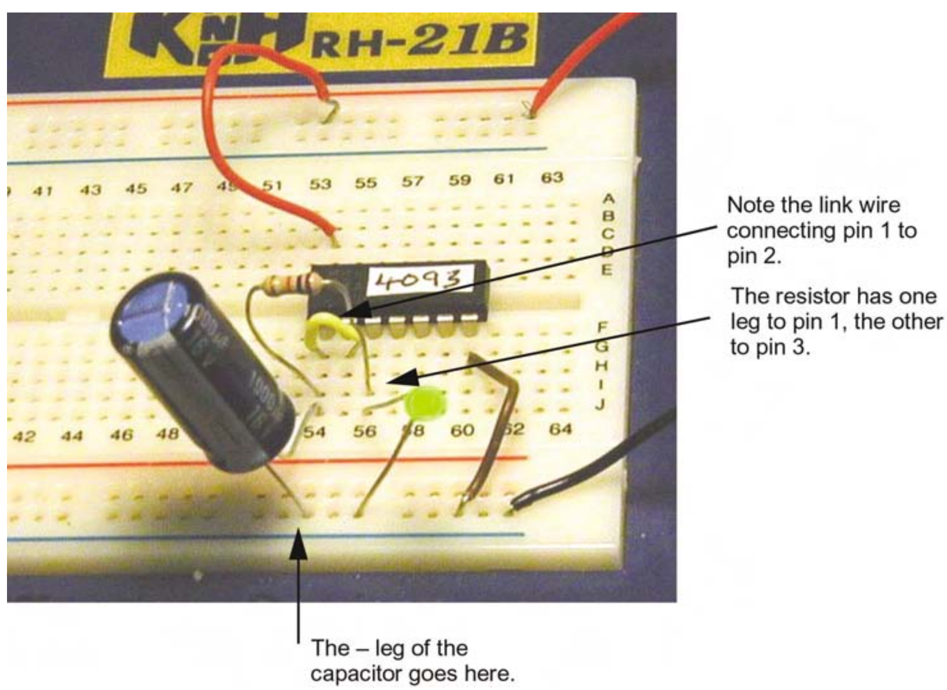
Goal
To learn how to make an LED flash in a simple circuit.

Outcome
Students will understand how varying capacitor and resistor values affect the flash rate of the LED.

Description
Students add a resistor and a capacitor to the circuit from the previous activity and observe the effect of varying the resistor and capacitor values on the flash rate of the LED.

Supplies
As in Session 5 plus 1 resistor and 1 capacitor.

Procedure
1. Build the circuit shown in the photo.



2. Count, and note, the number of flashes given in 1 second, or 10 seconds if the LED flashes quickly.

A. *There is no 'right answer' to this.Note that variations in the components make it unlikely that any two groups of students will get the same result. Also, it depends on the quality of the battery.*

5B: Making an LED Flash (continued)

3. Now change the capacitor and resistor for other values that your teacher has available. Investigate how the flashing rate changes as the capacitor and resistor values change. Note: take care how you do this. What is the systematic way (rather than trial and error)?
   (i) Write down short sentences to summarise your findings. E.g. 'As the value of the capacitor increases, the flashing rate …'
   Note: your circuit may appear not to work with some values of capacitor and resistor. Why might this be? There are two way it might seem not to be working (assuming you have not made a mistake in putting the circuit together).

A. As the value of the capacitor/resistance increases, the flashing rate decreases.'
Two things can go wrong: (i) if the values of the capacitor and resistor are too low, the flashing rate is so fast that the LED appears to be on all the time; (ii) if the values are too large, the LED won't switch on for several minutes, so it will also seem that the circuit has stopped working. (Unfortunately the latter possibility is possible as well.)

Things to think about

1. Write down at least two ways you could use a flashing LED circuit in a toy or some other device that people might buy. (It would be fairly easy to adapt the circuit to control more than one LED.)
   See earlier work on LEDs above.
2. Can you think of any uses for flashing LED circuits in industry? *Warnings of all kinds.*

Session 5, Activity C

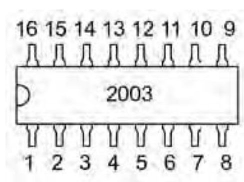
Controlling a Motor

In This Session:

Making motors turn

The 4093 chip is very useful, but some devices that you might want to use such as motors need more current to flow them than is good for the 4093. You may not have thought much about the way this chip works, but the current mainly flows from pin 8 through the output pin 3 and through the LED, buzzer etc. that is connected to it. The chip senses the voltage that is applied to the input pins 1 and 2, but almost no current flows through these pins. The chip will get very hot, and finally stop working if too much current goes through it. So, if we want to use a motor, as a device to turn on and off, we have to use another chip connected to the 4093 that can allow higher currents to flow through it. Such a chip has the code number 2003. Also, it is important to know that when motors are switched on or off, very high voltages can be produced. The voltages may only last for a tiny fraction of a second, but they can cause damage to the chips or other electrical components. A small electrical component called a diode can protect the circuit. Fortunately, the 2003 has a number of diodes built into it, so it can safely be used with small motors.

The numbering system for the 2003 pins is shown in the diagram below. When you use this chip, the negative of the battery MUST be connected to pin 8, and the positive to pin 9.



5C: Controlling a Motor (continued)

Goal
Students learn about the current capacities of different silicon chips and why this needs to be considered when using circuits to turn on and off other devices.

Outcome
Students will use a simple circuit to turn on and off a motor.

Description
Students build a circuit using a 2003 chip connected to a motor. They use the 2003 to turn the motor on and off. If they have time students can try adapting their previous circuits using the 4093 chip, a micro switch or a reed switch to turn the motor on and off.

Supplies
Components from previous activities plus 1 electric motor, and 1 2003 chip.

Procedure
1. Connect the 2003 chip into a circuit as shown in the photo opposite. You will use pin 1 to turn the motor on and off. Notice that the motor is connected between the positive of the battery and pin 16.
2. In the photo, you can see that one wire is connected to pin 1, but its other end is not connected to anything. Try connecting the free end to the positive of the battery, and then to the negative of the battery. What happens? Which of the following two statements is correct?
   (i) A positive voltage at pin 1 turns the motor on.
   (ii) A positive voltage at pin 1 turns the motor off.
   Students should find that (i) is correct.

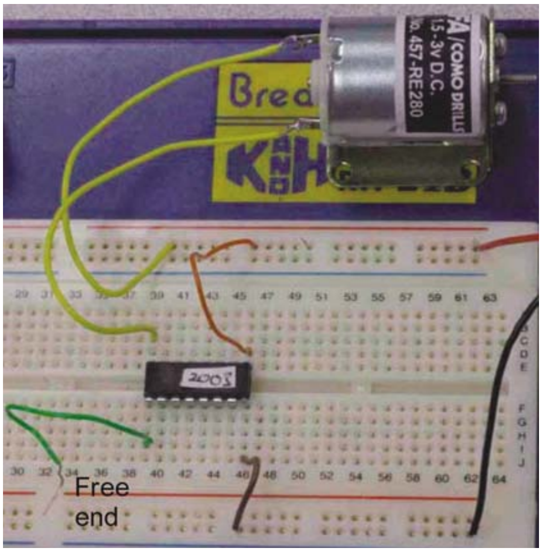
Exercises
1. The motor you have used turns very quickly (about 4000 revolutions every minute). Suppose you wanted to use it to drive a small four-wheeled buggy. Suggest a way of connecting the motor to the wheels so that the wheels only turn at 500 rotations per minute. Sketch a diagram to show how your idea would work.
   *Use gears. The diagram might show the motor's shaft with a small cog, which is used to drive a larger cog. The two cogs should have their number of teeth in the ratio 1 to 8. E.g suppose the smaller cog had 12 teeth, and the larger cog had 96 teeth. When the small cog turns through 360 degrees, 12 teeth have engaged with the larger cog, so the latter will have turned 360*12/96, i.e. 45 degrees. Thus the larger cog will turn once for every eight turns of the motor's shaft (=500 rotations per minute).*

5C: Controlling a Motor (continued)

2. Think of a way of making the motor turn on and off in short pulses. Build the circuit.
   The circuit would take the output produced by the flashing LED circuit and feed the signal into the 2003 chip.

Note: please do not let the motor run for more than a few seconds at a time. You may damage it if you leave it running for more than 10 seconds at a time.

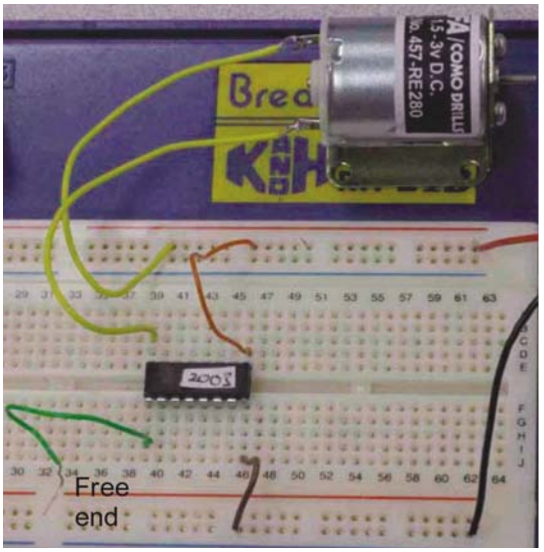
3. Now you can use the circuit you built with the 4093 chip that made an LED light to turn the motor on and off as shown in the photo below. If you look carefully, you can see that one wire is used to connect pins 1 and 2 together. Another wire goes from pin 1 but is not connected to anything else. (You will use it shortly.) Remember, the connections to the battery should be the last to be made. Connect the free end of the wire to the positive of the battery, and then to the negative of the battery. what happens?



4. Try swapping the two wires to the motor. Does it change the direction of rotation of the shaft?

5. If you have time, try adapting your previous circuits using a micro switch, or reed switch to turn the motor on and off.

5C: Controlling a Motor (continued)



Something to think about

1. With your partner, think of two ways you could use a motor in a project. (You don't have to use the circuits you have built, although you can if you want.) Write down the key points of your ideas.

Session 6

Making Machines and Observing Functionality

In This Session:

A Design, Build, Make It Go! (40 mins)
- Student Worksheet
- Student Reading
- Student Reading

B Gears, Cranks, Crankshafts, and Belts (40 mins)
- Student Worksheet

C Using Motors to Produce Motion (40 mins)
- Student Worksheet

This session really puts things in motion. In *5A: Design, Build, Make It Go,* students make rolling toys from a set of everyday materials in a mini-design challenge, and then recall prior experiences with simple machines. The activity *5B: Gears, Cranks, Crankshafts, and Belts* is an exploration of gears, cranks, crankshafts, belts. The last activity in this session introduces students to motors and explains how motors can be used to produce motion.

Supplies

One "Rolling Kit" Per Student
- 1 film canister with lid, with holes drilled in both ends
- 2 size #30 or #31 rubber bands (dimensions 6.5 cm x 3 mm x 0.7 mm, #31 is slightly heavier)
- 2 small washers
- 1 piece of thick drinking straw the length of the canister

One Crankshaft Kit Per Student
- Small box (250 ml milk carton will do)
- 3 pieces 16-gauge steel wire: one 20 cm length, two 7.5 cm lengths
- 1 straw
- Electrical tape or long bead (for crank handle)
- Several pairs of needle-nose pliers

Other
- Tools that use moving parts: eggbeaters, hand drills, winged corkscrews, flour sifters, ice cream scoopers, nut grinders, and manual can openers
- Miscellaneous gears, belts and wheels, wire, art supplies, and other materials of choice
- Legotechnic 8735

Making Machines

Key Concepts: Session 6

Session 6 explores fundamental physical science concepts of mechanical engineering. A rolling-toy design challenge begins students thinking about machines. Students explore the mechanics of simple machines and learn that most mechanical devices are really a set of simple machines working together. They learn how machine action can be transferred or change direction by experimenting with gears, wheels and belts, and crankshafts. The session culminates with the construction of an electronically powered mechanical buggy.

Key Concepts

Simple and compound machines make work easier by multiplying the force we are able to exert. Imagine trying to break a piece of wood apart using your bare hands. Now think how an axe helps you accomplish this task. The axe is a wedge, one of six simple machines.

Machines provide mechanical advantage to make work easier. "Work" is defined as *the application of force to move a load over distance*

Work = Force x Distance

Any machine makes work easier by reducing the force required to move a load. This is known as mechanical advantage. Machines can change the force we exert but not the amount of work done.

Simple Machines
There are six basic or *simple machines*, which alone or in combination make up most of the mechanical devices we use.

1. **Lever:** A see saw is a lever familiar to everyone. A lever is a stiff rod or plank that rotates around a fixed point, or *fulcrum*. Downward motion at one end results in upward motion at the other end. Depending on where the fulcrum is located, a lever can multiply either the force applied, or the distance over which the force is applied. There are three kinds of levers and which kind you have depends on where the fulcrum is set. These are all levers: see saw, wheelbarrow, hammer claw, crowbar, bottle opener, oar, fork, baseball bat and scissors.

2. **Inclined plane:** The inclined plane can be best described as a ramp or slanted surface, which decreases the amount of force needed to move an object to a higher level. On an inclined plane, the object travels a longer distance but it takes less force. These are examples of an inclined plane: wheelchair ramp, slide, rollercoaster and escalator.

Key Concepts (continued)

3. **Wedge:** A wedge is an inclined plane with either one or two sloping sides. It converts motion in one direction into a splitting motion that acts at right angles to the blade. Nearly all cutting machines use the wedge. A lifting machine may use a wedge to get under a load. the following are all examples of wedges: chisel, saw, screwdriver, scissors, door wedge, thumbtack, pin and nail.

4. **Screw:** The screw is an inclined plane wrapped around a cylinder. the advantage offered by the screw is that as it turns, rotary motion is converted into a straight motion. This motion can be used to move things apart (as in a car jack) or bring two objects (a screw drawing two boards together). These devices are screws or have a screw component: jar lid, light bulb, piano stool, clamp, jack, wrench, key ring and corkscrew.

5. **Wheel and axle:** When a wheel is locked to a central axle, as one is turned the other must turn. A longer motion at the edge of the wheel converts to a shorter more powerful motion at the axle. In reverse, a short, powerful force at the axle will move the wheel's edge a greater distance. The wheel and axle are the basis of these devices: doorknob, roller skates, eggbeaters, manual pencil sharpener and skateboard.

6. **Pulley:** A single pulley reverses the direction of a force. When two or more pulleys are connected together, they permit a heavy load to be lifted with less force, because the force is spread over a greater distance. Fixtures on flag poles, clotheslines, blinds, cranes and fan belts all rely on the pulley.

Compound Machines
A compound machine is made of simple machines acting together to perform work. For example, a rotary pencil sharpener is made up of a wedge and a wheel and axle. Students will see that many mechanical devices are comprised of component simple machines when they explore eggbeaters, winged corkscrews, manual can openers and other everyday household implements.

Compound machines redistribute force with gears, belts and crankshaft. Energy transfer between component simple machines is what makes a compound machine work. Gears, belts and crankshafts are mechanical components that often tie simple machines together, by either transferring a force or changing its direction.

Gear: The common or "spur" gear is a wheel and axle with lever "teeth". When force is applied to the gear, its teeth mesh with those of another gear, transferring the force to that gear. When one gear is larger than another, the turning rate changes. Adjusting relative gear sizes, or gear ratios, gives us a way to change how force is expressed. Anyone who has ridden a bicycle with multiple gears has changed force by adjusting gear ratios. Gears can change the direction of a force when their teeth are bevelled or when they are set at an angle to another gear. You can see this change in direction when you observe a rotary eggbeater in action.

Belt: Belts work with wheels and axles to transfer energy. A belt attached between two wheels or shafts transfers force from the one that is powered to the one that is not. A belt can change direction of a force when the wheel or shafts are set at different angles. It is advantageous to use belts when you want to connect components that are far apart. as with gears, if a belt connects wheels or shafts of different sizes, these will turn at different rates.

Key Concepts (continued)

Crankshaft: Crankshafts turn rotary (circular) motion into reciprocal (up and down) motion. Students will see how force changes direction when they make their crankshaft toy.

Potential and Kinetic Energy
Energy can be stored and then released in machines. Stored energy is called *potential energy.* released energy is called *kinetic energy.* Think about a windup plane. When you wind the propeller attached to a rubber band, your human energy is stored as potential energy in the wound rubber band. When you let go, the unwinding rubber band releases energy and powers the plane's propeller.

Friction
Friction is the resistance encountered when one body moves while in contact with another. Friction is the friend and the enemy of machines. In car brakes, friction from the brake shoe pressing against the drum is what causes the vehicle to slow. In this case, friction is an essential function. In other devices, friction causes problems. When component parts meet each other, friction between them can waste energy, produce unwanted heat and degrade materials. To make machines run well, engineers choose materials carefully, and design components to work together efficiently

More about Simple and Compound Machines

Advanced Technologies Academy
www.atech.org/faculty/dunne/about/SM*
This site explains simple machines with vivid, colourful graphics and simple explanations.

Boston Museum of Science
www.mos.org/sin/Leonardo/InventorsToolbox.html*
The Inventor's Toolbox on this site provides information on simple machines.

COSI Science Centre, Columbus and Toledo, Ohio
www.cosi.org/onlineExhibits/simpMach/sm1.html*
(Macromedia Flash Player* is required.) This site is best used as a guided demonstration.

The Franklin Institute
http://sin.fi.edu/qa97/spotlight3/spotlight3.html*
Simple Machines section shows six simple machines in action.

University of Texas
www.engr.utexas.edu/dteach/Experience/mechanisms/brief_overview.htm*
The Mechanisms site is a good review of the concepts of simple machines and mechanics.

Session 6, Activity A

Design, Build, Make It Go!

In This Session:

A **Design, Build, Make It Go! (40 mins)**
- Student Worksheet
- Student Reading
- Student Reading

B Gears, Cranks, Crankshafts, and Belts (40 mins)
- Student Worksheet

C Using Motors to Produce Motion (40 mins)
- Student Worksheet

Goal
Recall and gain experience with motion and machines.

Outcome
Make a rolling toy that travels 1-1.5 metres as an introduction to mechanical engineering.

Description
Students are given a set of materials and challenged to make a toy that rolls 1-1.5 metres on its own power. A follow-up discussion about design and students' tinkering experiences past and present helps students recall engineering concepts of mechanical engineering. A "recipe" for success is provided so the presenter can make a working version in advance and later guide the students' efforts.

Supplies
One "Rolling Kit" Per Student
- 1 film canister with lid, with holes drilled in both ends
- 2 size #30 or #31 rubber bands (dimensions 6.5 cm x 3 mm x 0.7 mm, #31 is slightly heavier)
- 2 small washers
- 1 piece of thick drinking straw the length of the canister

Rolling kit

6A: Design, Build, Make It Go! (continued)

Preparation

1. Make holes in the flat ends of the film canisters and lids. The holes can be drilled with a drill bit.

2. Cut drinking straws into lengths. They should be the length of the canister. (You can also use small pieces of a broken pencil if the straw is not strong enough.)

3. Place the other materials (2 rubber bands, 2 washers, piece of drinking straw) inside the canister and put the lid on. This is a "rolling kit."

4. Write the design challenge on the board or poster paper: Using any or all of the materials in your kit, make a rolling toy that travels 1-1.5 metres on its own power. It does not need to go in a straight line.

5. Provide measuring tapes or precut lengths of string.

6. Watch a short video clip that demonstrates how to make the rolling toy.

Rolling toy

This video can be found on the Design and Discovery website at www.intel.com/education/design/session05/activity1.htm

7. So that you can provide guidance as the students engage in the work, make a roll toy of your own using the following "recipe" for success (but let the participants design their own varied solutions to the challenge!):

   - Put the rubber band halfway through one washer. Thread one loop through the other loop and pull. The washer should be securely on the rubber band.
   - Poke the rubber band through the hole in the end of the film canister so the washer is on the outside.

6A: Design, Build, Make It Go! (continued)

- Poke the other end of the rubber band through the hole in the lid so the loop of the rubber band is on the outside of the lid.
- Hold the loop and put the lid back on the film canister.
- Put the loop of the rubber band through the second washer and then put the end of the straw through the loop, with most of the straw length extending beyond the canister. If there is slack in the rubber band, you may need to knot it around the straw.
- Turn the straw at least 30 times so the rubber band twists.
- Put your toy on the floor and let it go! (No one said the toys had to go in a straight line.)
- The second rubber band can be wound onto the non-capped end of the canister, to correct for its smaller circumference.

Procedures

Tinker With Toys

1. As students come in, give them each a “rolling kit,” direct their attention to the “Rolling Toy Design Challenge” on the board, and challenge them to build their rolling toy.

2. After 15 minutes or so of work time, give participants a 5-minute warning, and then let them demonstrate their toys to one another. (No one said the toys had to go in a straight line.) If they fail to make the toy roll, assure them that there is a method that works, and encourage them to continue trying later. Either way, proceed with step 3.

3. Guide a discussion, asking questions that cause budding engineers to reflect on the design process they just engaged in (successful or not), such as:

    - Is there any one “right” solution for this challenge? Why or why not?
    - What would you do differently if you had more time? Different materials?

6A: Design, Build, Make It Go! (continued)

- Can anyone tell about their process; when and why they might have switched to a new idea?
- What did you learn from watching each other?
- It is said you have to have a breakdown before a breakthrough. Can anyone relate to that?

Develop Concepts

1. Develop the concept of energy transfer and component parts: Tell student pairs to discuss how the toy is powered and be ready with an agreed-upon explanation for the group. Have them report, and probe for answers to these questions:

   - Where does the energy come from, and where does it go?
   - At what point is energy transferred from you to the toy?
   - At what point does potential (stored) energy change to kinetic (released) energy?
   - Is this a machine?

Wrap Up
Explain that many devices are made up of mechanical component parts that act in concert to perform work. The next activities will give them more experience with moving parts, some of which they may want to include in their personal design projects later on.

Have students read and then discuss *Reading: 6A: What is a Mechanical Engineer?*

Design, Build, Make It Go!

Worksheet: Session 6, Activity A

Make a Rolling Toy Design Challenge: Using any or all of the materials in your kit, make a rolling toy that travels 1-1.5 metres on its own power. It does not need to go in a straight line.

If you get stuck along the way, here are some hints:

- Consider a wind-up toy. How does it work?
- Wind-up toys convert potential energy into kinetic energy as they unwind.
- How is the energy stored and released? (Often this is a spring.)
- What could be used instead of springs to store and release energy?

Slinky

Reading: Session 6, Activity A

Patented by Richard James, Upper Darby, Pennsylvania for James Industries.
Filed 1 November 1945 and published as GB 630702 and US 2415012.

This is the familiar toy which consists of coils that move downstairs, along the floor, or from hand to hand. Richard James was a mechanical engineer working for the U.S. Navy. While on a ship undergoing trials, a lurch caused a torsion spring to fall accidentally from a table to the floor. Its springy movement made him think. When he saw his wife Betty that night he showed her the spring and said “I think there might be a toy in this.” Two years of experimentation followed to achieve the right tension, wire width, and diameter. The result was a steel coil with a pleasant feeling when handheld, with an ability to creep like a caterpillar down inclined planes or stairs, and an interesting action when propelled along the floor. Betty came up with the name of Slinky*, from slithering.

James managed to persuade Gimbels, the department store, to give him some space at the end of a counter. He would demonstrate the toy and hope to sell some of his stock of 400. It was a miserable November night, and Betty and a friend were on hand to buy a couple to encourage sales. They never had the chance, as crowds gathered around and the entire stock went in an hour and a half. A company, James Industries, was set up to make the product. A machine was devised which coiled 24 metres in 10 seconds. The price was $1 in 1945, which had increased to $2 by 1994. Over 250 million have been made, with some variations, including brightly colored plastic models. The only substantial change in the design is that the end wires are now joined together to prevent loose wires damaging, for example, an eye. The trademark was registered in the United States in 1947 and in Britain in 1946.

Besides the obvious fun possibilities, the toy has been used by science teachers to demonstrate the properties of waves. NASA has used them to carry out zero gravity physics experiments in the space shuttle. And in Vietnam, American troops used them as mobile radio antennae.

Reproduced with permission:
Van Dulken, Stephen. *Inventing the 20th Century, 100 Inventions That Shaped the World.* New York: New York University Press, May 2002. www.nyupress.nyu.edu*

What is a Mechanical Engineer?

Reading : Session 6, Activity A

What Do Mechanical Engineers Do?

Mechanical engineers turn energy into power and motion. Machines, tools, and equipment are designed, produced, tested, and improved by mechanical engineering teams. Examples include fuel-efficient cars, scooters, toys, power plants, hydraulic systems, medical devices, laser-based tools, sports equipment, measurement devices, and the list goes on and on… In fact, almost every object with moving parts that you encounter today involved a mechanical engineer.

In the future, mechanical engineers will continue to develop new materials, work on problems such as environmental pollution control and in the electric power, airline, and telecommunications industries. They will be involved with laser technology, computer-aided design, automation, and robotics.

Where Do Mechanical Engineers Work?

Mechanical engineers work in all areas of manufacturing industries. They can work in research and development, management, maintenance, and production operations. Some engineers become consultants in the research, design, and testing of technologies. Creativity combined with mechanical engineering skills is a great start for an inventor!

For more information on mechanical engineering as a career go to the resources section at the back of this folder. Students could be asked to familiarize themselves with the role of an mechanical engineer as homework.

Session 6, Activity B

Gears, Cranks, Crankshafts and Belts

In This Session:

Goal

Study moving machine parts to learn how force can be transferred or change direction to accomplish work.

Outcome

Make a crankshaft mechanism.

Description

After an introduction to the moving parts of machines (gears, cranks, crankshafts, belts, and wheels), students investigate these parts and make a crankshaft mechanism.

Supplies

One Crankshaft Kit Per Student

- Small box (250 ml milk carton will do)
- 3 pieces 16-gauge steel wire: one 20 cm length, two 7.5 cm lengths
- 1 straw
- Electrical tape or long bead (for crank handle)
- Several pairs of needle-nose pliers

Other

- Tools that use moving parts: eggbeaters, hand drills, winged corkscrews, flour sifters, ice cream scoopers, nut grinders, and manual can openers
- Miscellaneous gears, belts and wheels, wire, art supplies, and other materials of choice
- Crankshaft model (see below)

6B: Gears, Cranks,Crankshafts and Belts (continued)

Preparation

1. Collect a variety of mechanical devices that have visible moving parts (example: eggbeaters, hand drills), enough for one device per group of three students. A mounted manual pencil sharpener in the room (cover removed) can serve as one device. (Consider asking students to bring devices from home at the end of the previous day.)

2. Collect tools, including needle nose pliers, rulers or measuring tapes, and scissors.

3. Prepare a model crankshaft in a box. See *6B Worksheet: Gears, Cranks, Crankshafts, and Belts.*

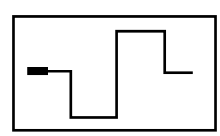
4. You can watch a short video clip that demonstrates how to make the crankshaft toy at http://www.intel.com/education/design/session05/activity3.htm

Procedures

Exploration: Look at Moving Parts

1. Distribute a variety of mechanical devices (egg beaters, etc.) that have visible moving parts, one to each group of three students. Ask these questions, and have each team answer and demonstrate:
   - Can you count the moving parts?
   - How do the moving parts connect to one another?
   - Can you name any of the moving parts (crank, gear, moving shaft, blade, spring)?
   - Can you find places where the force or motion changes direction (example: corkscrew wings press down causing the cork to pull up)?
   - Demonstrate how the device operates to perform work.

2. Introduce the **crankshaft** by showing a wire crankshaft made from a paper clip bent into the shape shown. Show how a crankshaft changes the direction of a motion from rotary to reciprocal.



3. Give students 10-15 minutes to investigate the components. Encourage them to consider using these parts in combination in mechanical devices they might make.

Construction

1. Make the crankshaft device, following directions on the worksheet. Students should take this basic device home and turn it into an appealing toy.

Gears, Cranks, Crankshafts and Belts

Worksheet: Session 6, Activity B

Make a Crankshaft Device

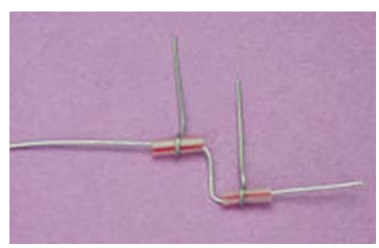
Do you remember playing with jack-in-the-box toys when you were small? They have a crank mechanism something like the toy you will make today. With this crankshaft toy, you will see how the direction of a force can be changed mechanically. Turning the crank around and around makes other parts go up and down!

Supplies

- Small box (250 ml. milk carton will do)
- 3 pieces 16-gauge steel wire: one 20 cm length, two 7.5 cm lengths
- 1 straw
- Electrical tape or long bead (for crank handle)
- Needle-nose pliers

Steps

1. Cut off the top of a milk carton to make a small box with one side open.
2. Turn the box so the opening is on the table, and drill or poke (using the wire) a hole in the right and left sides of the box at the same height.
3. Drill or poke two holes in the top. They should be in a straight line with the other two holes.
4. Cut two short pieces of straw about 1/3 the length of the box.
5. Wrap the end of one of the small pieces of wire around one of the pieces of straw. Make it secure, but not too tight, as the straw should spin freely on the wire that will go through it. Repeat with the other wire and the other straw.

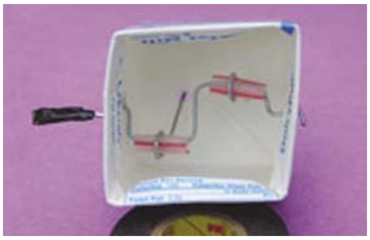


6. Place the straws (with wires dangling for now) over the long piece of wire, leaving one more inch of wire on what will be the crank handle end.
7. Make the centre two bends between the straws, leaving a straw-length section of wire between the bends.

6B: Gears, Cranks,Crankshafts and Belts (continued)

8. Bend the shorter non-crank end of the wire at the outside edge of one straw.
9. Bend the longer crank end of the wire at the outside of the other straw.
10. From the inside of the box, stick the non-crank end of the wire through one of the holes and bend the end on the outside of the box so it doesn't slide out. You will need to put careful tension to make this fit into the box. Try to keep the wire in the same form.
11. Reach into the underside of the box and gently turn the smaller wires so they poke through the holes in the top of the box.
12. Stick the other end of the wire into the other hole, and make two bends outside the box, making a crank.
13. Secure a large bead or electrical tape on the crank to make a handle.

Crank the handle and watch the wires go up and down. It may need some adjustment to get the best motion. Now it's all up to you! How will you turn the up and down motion into something fun?



Session 6, Activity C

Using Motors to Produce Motion

As with the electronics sessions 4 and 5 the following piece on Motors has been duplicated in the Students Booklet to make it easier for the students to follow. Any text in italics is in the Teacher Guide only. For more teacher notes on this activity please see teacher notes in resources section at back of the folder.

Goal

To investigate some aspects of using motors to produce motion.

Outcome

Students will use a Lego Technic kit to build a buggy and study how it works.

Description

This activity is designed to introduce you to some aspects of using motors to produce motion. A familiar example is the use of an electric mixer in food preparation; but no doubt you will be able to think of many more examples where motors are used. We can't easily investigate a food mixer in class; instead you will use a LEGO Technic kit to build a small buggy, and study how that works. You may do this work with your group partner(s); or you may do it as a class activity. Much of what you will learn applies to larger scale devices such as food mixers, or cars that use motors (whether they be electric, petrol or diesel).

Procedure

Exercise 1

Build the small LEGO buggy by following the instructions on the separate sheets. However, as you do this, write down brief notes and/or draw diagrams in answer to the questions below.

Do NOT connect the motor to the battery pack until you are told do so.

1. How many cogs are there on the large gear wheel?
2. How many cogs are there on the small gear wheel to which the large one connects?
3. The large and small gear wheels are at right angles to the axles of the buggy. How is the motion of the gear wheels transferred to the front axle?
4. Would you say the finished buggy is stable? Explain your answer.

6C: Using Motors to Produce Motion (continued)

Ask your teacher for permission to try out the buggy. Please do NOT leave the buggy switched on for more than a few seconds—otherwise the batteries run down very quickly.

Exercise 2

1. Work out a way to measure the speed of the buggy. You MUST write down your plan. You may be asked to discuss your ideas with other students.

2. When your teacher gives permission, try our your ideas. You should finish up with an estimate of the speed of the buggy in cm/second. How accurate do you think your estimate is? Could you improve the accuracy? If so, how?

3. The diameter of the wheels is about 3cm, so the radius is about 1.5cm. Use the formula for the circumference of a circle to calculate the circumference of one of the wheels.

   circumference = 2 x π x radius = 2 x 3.14 x radius

4. The circumference is also how far the buggy will go when the wheels revolve once. Use your result for the speed of the buggy to calculate how many times the wheels would turn in 1 second. Your answer will have units of 'revolutions per second'. Then convert your answer to revolutions per minute. Give your answer as a whole number. Write down your results, e.g. by saying 'The wheels turned at XX revolutions per second', 'The wheels turned at XX revolutions per minute'.

Now we shall try to estimate the speed of the motor itself. You will remember that the wheels are driven using gear wheels. The first thing to do is to work out how the gears affect the speed of the buggy.

Exercise 3

1. If the large gear wheel goes round once, how many times will the small gear wheel go round? (Look back to your answers in Exercise 1.)

2. Suppose the wheels were turning at 300 revolutions each minute, how fast would the motor actually be turning? Check your answer with your teacher before continuing with the next question.

intel Education

6C: Using Motors to Produce Motion (continued)

3. Now using your answer to question 4 of Exercise 2, estimate the actual speed of the LEGO motor.

4. In the information that LEGO provide about the motor, it says that it turns at about 350 revolutions per minute. How does your answer compare with that figure? Why do you think your result is likely to be at least a little different from the one LEGO claims?

More about gears and using motors
You should have discovered that the effect of using a large gear wheel attached to the motor, and a small gear wheel connected to the wheels makes the wheels rotate faster than the motor turns. In such a case we say that there is 'high gearing'.

Questions

Q.1 Suppose you wanted the buggy to move much more slowly than the motor turns. How would you make this happen? (This arrangement could be called 'low gearing'.)

Q.2 Imagine the buggy was very heavy. Would it be easier for the motor to move the buggy using high gearing, or low gearing?

Q.3 Look at the picture of the food mixer opposite. You can see on the side a lever near a series of numbers. What do you think the lever is for? Why are different settings needed on a food mixer?

Q.4 If you could see inside the mixer, suggest (in a simple way) what happens inside it when the lever is moved.

6C: Using Motors to Produce Motion (continued)

Follow-up work

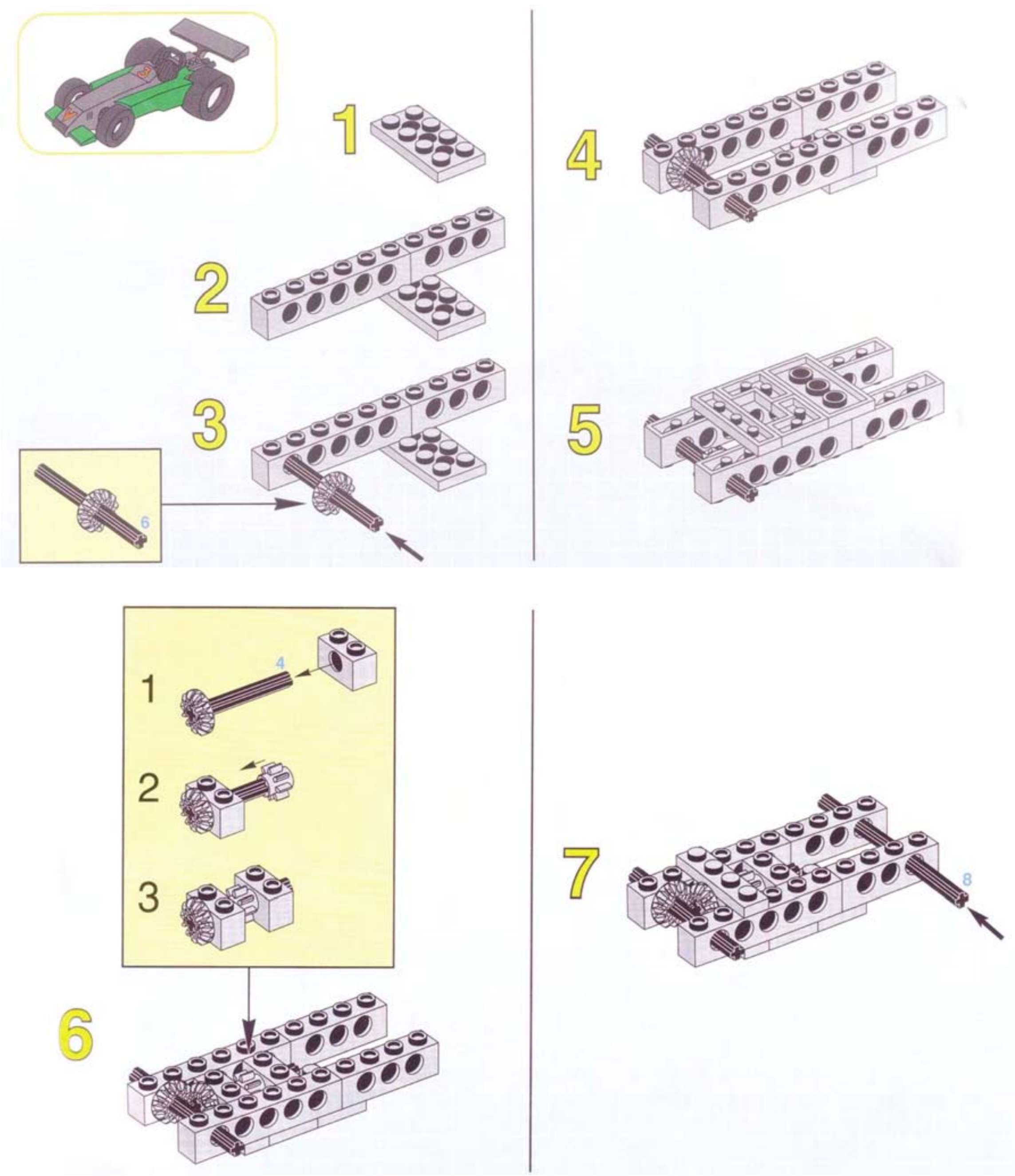
1. Most students want to learn to drive a car. If/when you take driving lessons, one of the most tricky things to do is to learn how to use the clutch pedal and change gears properly. Find out what the clutch does, and briefly write down what you find out. You may be asked to outline your findings to the rest of the class.

2. Most cars run on petrol or diesel fuel. However, car engines are not very efficient, and much research is taking place on trying to find more efficient engines. Some manufacturers are investigating the use of electric motors. Find out about alternatives to petrol an diesel engines. (Hint: try putting words such as 'Prius', 'energy efficiency', 'fuel cells" into Google or some other search engine on the internet.)

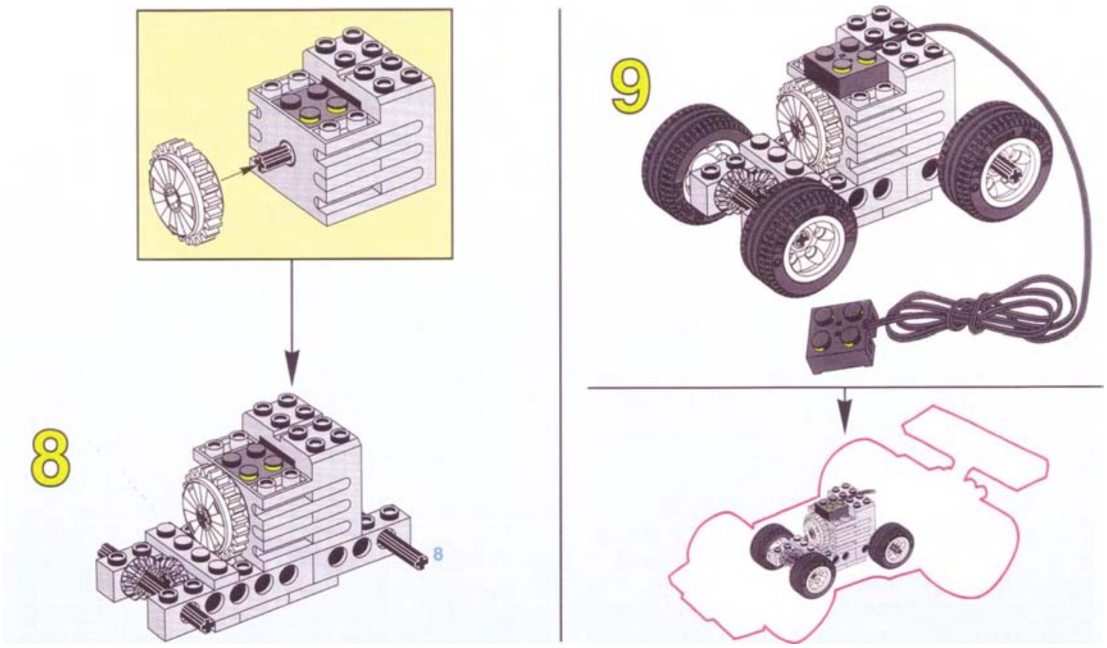
3. Look carefully at a food mixer that you may have at home. What are the key features of its design? Is it easy to use? Does it have any faults? Make some suggestions for improving the mixer so that it would be more appealing to customers.

Using Motors to Produce Motion

Worksheet: Instructions for making the LEGO buggy



6C: Using Motors to Produce Motion (continued)



Notes:

Session 7

Robotics

In This Session:

A Setting the Scene (40 mins)
- Student Worksheet

B Programme the Human Robot (40 mins)

C Robot Locomotion and Interaction (40 mins)
- Student Worksheet

D Robot Applications (40 mins)
- Student Worksheet
- Student Reading
- Student Worksheet

E Robot Programming (40 mins)
- Student Worksheet

Self Directed Learning

Depending on the time available, the students can undertake self directed learning rather than engage in purely classroom work. Some activities in the session can be undertaken outside the classroom environment.

What is a Robot?

This session will establish the students' current knowledge and perceptions of what a robot is. Perceptions of what constitutes a robotic device may be narrow and limited. Each student should write down three robots that they know of in their workbook and they should be encouraged to be as diverse as possible. In the classroom, all suggestions should be written down on a board or flipchart. Typically they will have included examples from film and TV advertising.

Examples: Elevator, Dishwasher, Bomb Disposal Robot, Mars Sojourner, Dalek, Lawn Mower, Doll, Citroen Picasso, Cruise Missile, JCB, Unmanned surveillance aircraft, CNC lathe, Undersea rescue and research vehicles, TV and security cameras, Robot Wars contestants.

Session 7, Activity A

Setting the Scene

Everyone has observed a robot in action or even interacted with one. This module helps us to expand our knowledge of the world of robotics. We will identify many of the different types of robot in general use. Next you will carry out an activity that illustrates some of the issues that arise in the programming of these devices. Finally we will get our hands on Quadrabotz, our educational robot.

A Quick Introduction

The word robot is often applied to any device that works automatically or by remote control, especially a machine (automaton) that can be programmed to perform tasks normally done by people.

Before the 1960s, robot usually meant a manlike mechanical device (mechanical man or humanoid) capable of performing human tasks or behaving in a human manner. Today robots come in all shapes and sizes, including small robots made of LEGO, and larger wheeled robots that play robot football with a full size ball. What many robots have in common is that they perform tasks that are too dull, dirty, delicate or dangerous for people. Usually, we also expect them to be autonomous, that is, to work using their own sensors and intelligence, without the constant need for a human to control them. According to this definition, a radio controlled aeroplane is not a robot, neither are the radio controlled combat robots that appear on television. However there is no clear dividing line between fully autonomous robots and human-controlled machines. For example the robot that performs space missions on planets like Mars may get instructions from humans on Earth, but since it can take about ten minutes for messages to get back and forth, the robot has to be autonomous during that time.

A robot has been developed that moves around the hospital wards under the control of a consultant who is based in another part of the country. They can speak with patients and visually examine them using a video camera.

Another robot is used to carry out physiotherapy on patients thus saving the valuable resources of a qualified professional.

Brainstorm - What is a robot ?

Worksheet: Session 7, Activity A

You will have seen robots in action in film, in the news, on documentaries and in real life. Write down the names of three of these and the function that they were carrying out.

Robot Name	Function

Some formal definitions
The technical people have attempted to come up with really fancy definitions such as:

1. An intelligent robot is a machine able to extract information from its environment and use knowledge about its world to move safely in a meaningful and purposeful manner.

2. A robot is a system which exists in the physical world and autonomously senses its environment and acts in it.

3. A robot is a re-programmable, multi-functional, manipulator designed to move material, parts, or specialised devices though variable programmed motions for the performance of a task.

4. Robotics is the intelligent connection of perception to action.
   Which one of these best describes the robot? You could come up with a better definition, have a go. We will discuss these in class. Also we will go through everyone's 3 robot names and record these on the board. You should write down all of the robots on the list as you will need this in the next session.

Ask the students to select which definition best describes robotics to them and select a few people to reflect on why one definition appeals to them. Then ask for their own suggestions. There is a debate amongst the experts about what really constitutes a robot, so it is perfectly valid for the students to argue the case for and against the dishwasher for example. It may not look like the Mars Sojourner but it is computer controlled to take in specific amounts of water, heat it to the correct temperature, spray the dishes for a specified time having added the detergent first and then empty out that water and begin the rinse process!

Session 7, Activity B

Programme the Human Robot

In This Session:

This activity is designed to illustrate the task of programming a robot to navigate obstacles. Have the students write down the avoidance commands that they will issue to the robot when an obstacle is encountered. They must stick to these commands until they have identified the weaknesses in the programme and propose modifications. Discuss possible changes, implement them and monitor the results. An alternative to this exercise to have the blindfolded student pick up an object with the outstretched hand and place it in another location. All of their movements being guided by their colleague issuing commands of "Forward, Right, Up, Down, Open Fingers, Close Fingers etc."

You are in Control

A volunteer is asked to be the robot and is blindfolded. In the room where there are desks and other obstacles, the "robot" slowly steps forwards with their arms outstretched to feel the desks. The "robot" will come in contact with a desk and call out either "Right Obstacle" or "Left Obstacle". You will have written some simple instructions that they must follow when, for example, they touch a right obstacle. This might be:

1. Step back
2. Turn 90º to the left
3. Continue stepping forward

You must always give just the instructions or programme that you have written down. After a couple of tries you can modify your programme to make the "robot" navigate the obstacles more efficiently.

The Honda Asimo Robot

7B: Programme the Human Robot (continued)

Lets have a Competition
This exercise can be a competitive team exercise between two robots and their respective programmers. One group of students could be assigned the task of designing a fair obstacle course to be used by the competing teams.

Teams of three students will compete to see who has written a programme that controls the movement of their "robot" through an obstacle course in the shortest time. This can be undertaken after the class session.

Demo the Quadrabotz
The teacher loads the programme "Demo1.bbg". This programme tells the Quadrabotz to continously walk forward until it senses an obstacle on its right or left. It then takes the appropriate steps to avoid that object before resuming the forward walking motion. These are some points of discussion:

- Quadrabotz always takes the same avoidance steps for, say, the right obstacle and this may not be enough to get around it.
- Quadrabotz cannot decide to do something different until the programme is changed.
- It may back into something because there are no proximity sensors on the rear.
- While it is avoiding an obstacle to the right, it may crash into an obstacle on the left because during the avoidance manoeuvre the sensors are deactivated.
- Identify the shortcomings and possible improvements to this programme.

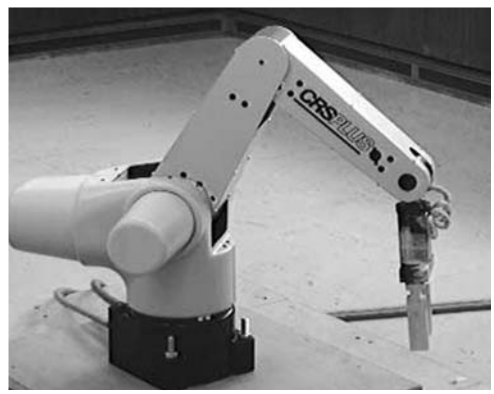
Session 7, Activity C

Robot Locomotion and Interaction

In This Session:

In this activity we will look at how various robots move about and interact with the environment. You will also identify parts of the Quadrabotz's anatomy. In addition we will learn how to programme Quadrabotz using a PC.

- Robot locomotion systems
- Sensing and interacting with the environment
- The anatomy of Quadrabotz
- The Quadrabotz programme editor



A manipulator arm used to teach robotics

intel Education

Robot Movement – Locomotion System

Worksheet: Session 7, Activity C

Locomotion Systems
Using the list of robots from the brainstorming session, pick examples for each locomotion system in the following table.

Locomotion system	Robot
Move on wheels	
Move on Tracks	
Walk	
Fly	
Swim	
Remain Stationary	

Sensing and interacting with the environment

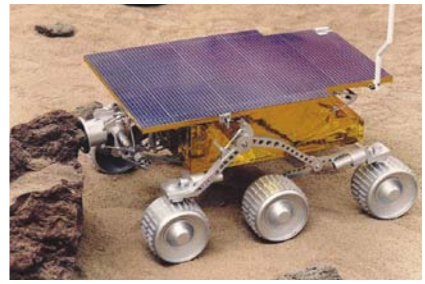
Imagine if a robot could not interact in any way with the environment around it. Can you imagine what value it would be? Think about it! The reality is that it would be completely and totally useless! Take two examples of robots from the brainstorm list and describe how they react with the environment.

Bomb disposal robot

Robot Name	How it senses and interacts with the environment

7C Worksheet: Robot Locomotion and Interaction (continued)

The students present their list of locomotion systems to the class. This exercise broadens the notion of robots as moving and fighting etc. They might even appear quite lifeless or mundane!


Mars Sojourner

The students report back to the class with their suggestions of how the robots interact with the environment.

Some examples of sensors and actuators:

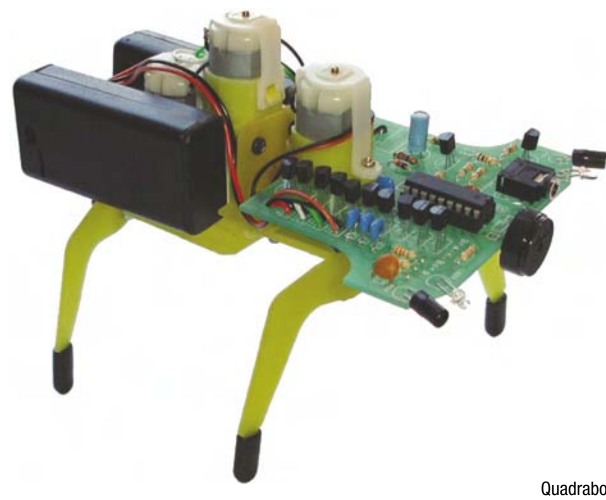
- *Touch sensors – micro-switches*
- *Visual – video camera*
- *Audio – microphone*
- *Distance – passive infra-red detectors as used in burglar alarms and ultrasonic transmitters and receivers similar to what the bat uses*
- *Temperature – temperature sensors used in washing machines, heat seeking missiles*
- *Car assembly robots use welding tools and sockets on the end of the arm or the manipulator*
- *The Bomb Disposal Robot may use a manipulator with crude fingers and also may have a manipulator with a shotgun mounted on it*

Energy Sources
If a robot is to move around then it nearly always gets its power from batteries. Providing they are charged up, batteries provide a steady stream of energy. Robotic forklift trucks are often used in industry for packing shelves. When they sense the batteries going low, they go to the "sick bay" and plug themselves in to the charger. The Mars Sojourner robot uses solar power to keep the batteries charged. Robots used in car assembly are usually stationary and can be connected to mains power. Have a look around the school, town and in your own home and try and find at least one item that is powered by:

1. Rechargeable batteries ______________________________
2. Non-rechargeable batteries ______________________________
3. Mains ______________________________
4. Light ______________________________
5. Movement ______________________________

7C Worksheet: Robot Locomotion and Interaction (continued)

Exercise 3
Identify parts of the Quadrabotz's anatomy
On the blank diagram the students should label the following items that make up the robot, obviously without a knowledge of electronics some components may have to be guessed at.



Quadrabotz

Quadrabotz's anatomy
On the photograph of Quadrabotz see how many of the following parts you can label:

- Front, middle and back motors.
- Left and right LEDS and photo detectors
- The micro-controller
- Battery packs
- The PC programming socket
- On/Off switch
- Piezo sounder

Manual Dexterity Exercise
This exercise will illustrate the freedom of movement and sensitivity of the human hand. The student is asked to tie their shoelaces using a pair of pliers in each hand. While some robots have much more sophisticated manipulators than this, no artificial hand has been developed to match all of the attributes of the human hand. Specific industrial tasks will only need to emulate the hand in a limited way like picking up an object using thumb and forefinger. Robots may do a much better job in these circumstances because they can be more accurate for placement, not so heat sensitive and be able to handle much greater loads.

Quadrabotz *program editor*
The students can use the tutorials that come on the Quadrabotz CD to learn how to programme the robot. The following programs may be loaded and run:

`Demo2.bbg`
This program causes the robot to beep and move backwards when you bring your finger towards either sensor.

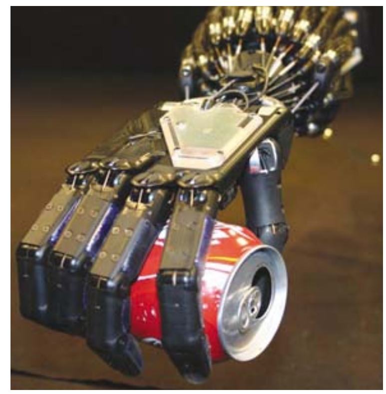
`Demo3.bbg`
This program counts the number of times that you put your finger in front of the left sensor. When you put your finger in front of the right sensor it multiplies the count by two and beeps the number of times corresponding to the answer. Students can try changing the program to multiply by three or divide by some number.

Session 7, Activity D

Robot Applications

In this activity we will look at specific robot applications and the issues that arise in each one. We will also see if robots will take over the world and how we would divide up the work between humans and robots. You will also do some more programming here.

- Discuss robot applications
- Strengths / Weaknesses
- Programming



Robotic Hand

Strengths and Weakness of both Robots and Humans

You may have seen the series on TV called "Robot Wars" where ordinary people built their own fighting machines that were remote controlled. The weapons were quite deadly with robots using hammers, flippers, cutting discs and brute force to try and defeat the others. There are many things that robots can do better than humans and vice versa. Each has their own strengths and weaknesses. Robot submarines have been used to go down to great depths in the sea to take samples, photograph the sea bed and to carry out rescue missions. The surface of Mars does not have an atmosphere or reasonable temperatures to support human life, this is why NASA built the Mars Sojourner to explore the surface of this planet. Tidying up your CDs is a bit of a chore. Imagine if your job was to take a CD from the burner and put into the case and you were expected to do 1000 of these every day! It would drive you nuts! Robots love this sort of work. Can Robots like or dislike work?

intel Education

Robot Applications

Worksheet: Session 7, Activity D

In the grid, list out three strengths and weaknesses for both humans and robots.

As the students report back, their own suggestion can be supplemented as necessary with some of the following:

Human	Robot
Strengths: • *Creative* • *Has many sensory inputs* • *Very powerful computer (brain)* • *Can learn* • *Can adapt to new environments*	**Strengths:** • *Never gets tired* • *Never gets bored and rebellious* • *Consistent worker and programmable* • *Can be very precise* • *May not need air to breath* • *May withstand more extreme temperatures* • *May be very strong* • *Can be manufactured on demand*
Weaknesses: • *Needs food, water and rest* • *May get into bad mood* • *Has 'off' days* • *Usually not absolutely consistent* • *Has variable body strength* • *Must have comfortable temperatures* • *Does not come in really small sizes*	**Weaknesses:** • *Pretty dumb* • *Limited sensory inputs* • *A mere computer for a brain* • *No feelings* • *Not versatile* • *Limited range of actuators* • *Programmed by humans who have weakness!* • *Can only learn simple facts*

Robot Applications

Reading: Session 7, Activity D

Programming
Every computer from the tiny one that controls Quadrabotz to the world's biggest super-computer understands just one's and zero's. All of these computers depend totally on humans to tell them what to do. Humans must program every step of the computer's activity whether that is to carry out a calculation, play a game or guide a missile. Quadrabotz is no exception. You can write the program on a PC and send it to the robot via the communications lead. Quadrabotz will faithfully follow your every command, no matter how silly or wrong they are! For instance we can tell Quadrabotz to beep, wait a moment and continuously repeat this action. Quadrabotz will keep doing this until its battery runs down. This not very useful you will agree but it just proves that you are in control of Quadrabotz, not the other way around. The wonderful thing about programming is that you can take what seems to be a collection of simple commands and put them together to create a really useful function. It is bit like painting where the artist works with a palette of paints to create a wonderful picture. So two of the most attractive things about programming are creativity and control. Given that you have total control and also given that we all make mistakes it is to be expected that our programs will contain errors and the robot will not perform as expected. Errors are an inescapable part of the task of programming. The programmer accepts this fact and continuously modifies the program removing all the errors and ensuring that it performs exactly the task it was designed for. There are two main categories of error:

Logical Errors: You want the robot to move forwards but you give it the command to move backwards. You only discover these errors when you run the program.

Syntax Errors: You have given the command to the robot to `burp(200)`. The program editor will actually tell you that this command is unknown to Quadrabotz when you attempt to download the program. The correct command spelling is `beep(200)`.

Don't worry about any errors that arise, this is an everyday part of programming. You cannot instruct Quadrabotz to self-destruct, unless you tell it to walk off the side of the table! In the real world, errors that arise in programs may not be so harmless.

A programming error in banking software might cause an ATM to give you €100 when you requested €10 even though you only had €20 to start with in your account! Banks do an awful lot of testing on their software to ensure that this does not arise.

7D: Reading (continued)

Aeroplanes are controlled by moving flaps on the wings and this is true of the most modern jets. In older planes the pilot's joystick was connected by a steel cable to the flap mechanism for direct control. Modern jets have a joystick just like on a games machine. The joystick is connected to a computer. The program in the computer monitors the movement of the joystick and then moves the flaps by the correct amount. A logical error in this program that caused the plane to go down when the pilot actually pulled the joystick to go up would be a disaster. Understandably, these programs are tested for years before they are released for commercial use.

Robotic lawn mower

Thankfully we are not working on such mission critical software so we can relax and have fun with Quadrabotz.

Pilot's joystick on the Airbus A330 just like a games machine!

An aeroplane on automatic pilot is a giant robot. It senses the effects of air currents and continually adjusts all of the various controls to provide a smooth flight. It will even execute a complex series of turns as it follows a flight plan from, say, Dublin to Athens. The pilot and co-pilot could both sit with the passengers and watch the in-flight movie but this would obviously cause panic.

Robot Applications

Worksheet: Session 7, Activity D

Quadrabotz

Load "`Exercise1.bbg`"
This program delays for 20 jiffies. There are 20 jiffies in 1 second. Quadrabotz starts to run the program following each instruction faithfully. To start with, it does nothing for 1 second. The next line tells it to do a beep(220). It then goes back to the first instruction and repeats the whole program again. This causes Quadrabotz to beep once a second.

```
Delay(20)
Beep(220)
```

Write a program that will make two beeps one second apart, wait for two seconds. Quadrabotz will continuously execute your program so that you should hear BEEP-BEEP SILENCE(2 Secs), BEEP-BEEP SILENCE(2 Secs), etc.

Session 7, Activity E

Robot Programming

In This Session:

In this final activity we will do some more programming of Quadrabotz. Having had some exposure to this robot you will become part of the design team to develop the next generation Quadrabotz. This will involve taking a critical view of the technology of Quadrabotz and identifying where improvements can be made. The last part of this session will consist of a brainstorm to suggest how Quadrabotz might be used in a robotics project.

- Analyse and program a gait
- Quadrabotz design teams
- Some ideas for a robotics project

Analyse and Program a gait

A gait is a style of walking and is simply a combination of movements of the three motors on Quadrabotz. Rather than having to program these movements yourself every time you wanted the robot to walk, the programming language has some high-level commands like Gait(gFwd). This command simply causes the motors to move in the right sequence so that the robot steps forward once. Your task is to examine the movements of the motors and the sequence that they operate in. You can then write your own program using the low-level Motors command to reproduce this same gait or maybe one that works even better!

intel Education

Programming

Worksheet: Session 7, Activity E

Quadrabotz design teams

Congratulations! You have now worked with Quadrabotz for a short while and you qualify to join the Quadrabotz engineering design team. You will be split into four separate teams to carry out an evaluation of version 1 of Quadrabotz and you will decide on what improvements need to be made for version 2. It is designed to be an educational robot and you have already learned many things from Quadrabotz version 1. There are four design teams looking at the following aspects of the design:

1. **Locomotion**
2. **Sensing and interacting with the environment**
3. **Intelligence**
4. **Power**

Each functional team will take 20 minutes to evaluate Quadrabotz and will report back to the executive design team where you will defend your well thought-out designs.

Just to get you thinking here are some issues that you may wish to consider as you develop the next generation Quadrabotz.

Team - Locomotion

- As a walking robot, how useful is it?

  ____

- What environments is this walking robot particularly suited to and what factors, if present, would cause problems?

  ____

- What are the limitations (ability to climb, step over stones, walk through grass etc.)?

  ____

7E Worksheet: (continued)

- Would two legs be better than four and what issues would that give rise to?

- What other system of locomotion would be more useful and fun to work with and learn from?

Team – Sensing and interacting with the environment

- What can Quadrabotz currently sense in the external environment?

- What additional things would it be useful for it to have an awareness of?

- If the Locomotion Team decide that the robot should walk on just two legs, how will it maintain its balance?

- Are there any manipulators that would be useful to include on the next generation robot?

- Is the beeper sufficient as a sounder?

- What other sound would be useful to make?

Team – Intelligence

- From what you have seen of the programming environment, is Quadrabotz really smart enough?

- Are there things that you would like to do, like more complex maths, or have the ability to measure distances?

7E Worksheet: (continued)

- Do you think the programming environment is OK for writing instructions for the robot? Are there improvements that you would make?

  ____

Team – Power

- Quadrabotz would certainly not survive long in a Robot Wars tournament, but do you think that it is powerful enough as an educational toy?

  ____

- If you feel that it is a bit of a weakling, in what ways would you beef it up? Bear in mind that more powerful batteries may be required.

  ____

- How would you be able to guarantee that the robot would run forever?

  ____

- How would you recharge the batteries?

  ____

- Are the 4 AA batteries sufficiently powerful to keep the robot going for a reasonable amount of time?

  ____

Projects Brainstorm

- **Light source seeker**. Quadrabotz can be placed in a dark room and programmed to locate and walk towards a torch light.
- **Item counter**. The obstacle detection feature could be used to sense when an object has passed in front of the robot. You could then programme it to beep for every ten items that passed by.
- **Oversize rejection**. A common issue in manufacturing is to automatically reject an item on the assembly line that is out of specification e.g. too wide or too tall. Quadrabotz could be positioned so that the obstacle detector was triggered by an oversized item and the front leg could then be programmed to kick the item off the assembly line. The assembly line track can be powered from one of the motors.

7E Worksheet: (continued)

- **Automatic traffic barrier.** The right sensor could be used to detect a car approaching the barrier. The front leg could then be used to raise the barrier. When the car triggers the left sensor the barrier is dropped.

- **Quadrabotz on wheels**. Two motors are attached to the two rear wheels of a three-wheeled cart. The single front wheel can be a castor type. The cart will be steered by moving one of the rear wheels at a time.

Links

Computer Science Lecture Notes "Introduction to Robotics"
http://www-scf.usc.edu/~csci445/

The NASA robotics site for educators
http://www.nasa.gov/audience/foreducators/topnav/subjects/technology/Robotics.html

Notes:

Thinking Creatively about Problems and Solutions

Session 8

The 3 R's of Problem Identification

In This Session:

A Revisit (40 mins)
- Student Worksheet
- Student Discussion + H/W

B Research (40 mins)
- Student Worksheet
- Student Discussion + H/W

C Refine (40 mins)
- Student Worksheet + H/W

D SCAMPER to Solutions (H/W)
- Student Worksheet

So many problems to solve and improvements to make. How do you decide which one to tackle? In this session, students revisit and refine their broad list of problems, needs, and improvement ideas (started in Session 2) to identify one design opportunity as their project. They use a variety of observation and data collection strategies to consider what exactly needs fixing, developing, or improving.

Students refine and focus on a problem to solve from the perspective of the users' needs. They write a problem statement, a description of the context for the problem, and a proposed solution.

In the first activity, *8A: Revisit*, students revisit their list of design opportunities started earlier in Session 2, *Design Opportunities are Everywhere*. Here, they develop the criteria for choosing a problem to pursue. In *8B: Research* and *8C: Refine*, students refine their list of problems and conduct market research by gathering information about the nature of the problem. They can do this by going off site to conduct a survey and collect data about the user, the user's preferences, and the realities of the user's life, environment, and behaviors. The SCAMPER brainstorm technique is used in *8D: SCAMPER To Solutions* to help students begin to think about the solutions for the design opportunity which they can do as home work. Students should each have one project in mind and about five possible solutions by then.

Intel Education

The 3R's of Problem Identification

Key Concepts: Session 8

In Session 8 students use product research to gather information about the nature of their design problems in order to narrow their choices. Students then learn about user needs by conducting surveys and using the data to choose one design opportunity that is compelling to them. Once students know the design challenge they want to pursue, they move to Step 3 of the design process - Brainstorming Possible Solutions to the Problem.

Key Concepts

During this session students are introduced to product research methods to help refine their design problem. These methods include asking potential product users probing questions and studying user data through surveys and observation. Understanding the user of the product is critical to product design. This process, called market research, focuses on the collection and study of user preferences toward new or existing products.

Surveys allow for gathering data about a user, a user's preferences, and the context of a user's life and environment. When designers understand their users, they can design with them in mind. A survey provides a way for designers to get specific information about a user. Questions used in a survey should help gather data about the problem and the user

Some question examples include:

- What do you find frustrating about this particular product?
- What aspects of the product do you find useful?
- What changes would you like to see made to this product?
- Would you purchase this product if (describe change)?
- How often do you use this product?

Surveys do have drawbacks because participants might give information about what they believe, not on what they do. An integrated approach to product research is often necessary to get a better understanding of the user.

An additional method for gathering information is through observations. Ethnography is a field of product research that uses observation as a method for gathering information. Ethnographic studies can be conducted by sending an observer to watch people use a specific product. By observing behaviour, researchers discover user needs that are not being met and possible design solutions that might meet those needs. IDEO (www.ideo.com*), a product design firm, uses ethnographic studies as a method to come up with design solutions. IDEO designed a concept vacuum cleaner that follows the user during cleaning, after conducting many user observations to understand the limitations around current vacuums. The model they designed addressed numerous issues that frustrated vacuum cleaner users.

Key Concepts (continued)

More about Product Research and Design

Industrial Designers Society of America (Editor) and Groddich, Kristina (Introduction). *Design Secrets: Products: 50 Real-Life Product Design Projects.* Gloucester, MA: Rockport Publishers, 2001.

Kelley, Tom. *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm.* New York: Doubleday, 2001.

The resorces provided below are design agencies. Reviewing these Web sites may be helpful in learning how professional companies develop products.

IDEO, www.ideo.com*

ZIBA Design, www.ziba.com*

ECCO Design, www.eccoid.com*

I.D. Magazine, www.idonline.com*

Session 8, Activity A

Revisit

In This Session:

A Revisit (40 mins)
- Student Worksheet
- Student Discussion + H/W

B Research (40 mins)
- Student Worksheet
- Student Discussion + H/W

C Refine (40 mins)
- Student Worksheet + H/W

D SCAMPER to Solutions (H/W)
- Student Worksheet

Goal
To add to and prioritize the list of problems and improvements that students began in Session 2 *Design Opportunities are Everywhere*.

Outcome
Identify three problems or improvements (design opportunities) to focus on.

Description
Students generate additional ideas to add to their list of design opportunities, looking for needs, problems, or improvements. They then go through a prioritization and selection process to narrow their list.

Supplies
None

Preparation
Be sure to ask students to take out their list of design opportunities from *2C Worksheet: Design Opportunities Are Everywhere*. (They should have been adding to this list throughout the sessions.)

Procedures
In this activity, students revisit their list of needs, problems, or improvements that they began earlier. This is Step 1 of the design process: Identify a Design Opportunity. Students should see that opportunities are everywhere and often come from a need, problem, or improvement to an existing solution.

Expanding the List

1. Provide some time for learners to add other ideas to their list that may have come up throughout the previous sessions. In doing so, their ideas should come from observations that they've made based on frustrations with particular everyday objects.

2. Give some examples here. For example, perhaps some students in the class are left-handed. They may have trouble using a computer mouse which is designed for a right-handed person. They might like to see adaptations made to a mouse so that it is suitable for a left-handed person.

8A: Revisit (continued)

3. Have students look around the room and choose something in the room. Now, ask them to consider what problems they have using this item. This might be a problem with the entire product or with one part of the item. Now, ask them to come up with a way that they would like to see it improved. Go around the room and ask students to share. You might find, for example, that someone doesn't like the pencil sharpener in the room. She doesn't like the fact that you have to constantly take out your pencil to see if it is sharpened. She would like to see the sharpener indicate when a pencil is sharpened. Remind them to think about function as opposed to form, the way it works as opposed to the way it looks. Ultimately, the goal is for them to re-engineer a product to make a functional improvement.

4. Students can also apply the Activity Mapping that they learned in *2C: Design Opportunities Are Everywhere*, to help them identify a problem. They can develop the Activity Mapping individually for a problem that interests them. This is a useful tool if they have difficulty coming up with a design challenge. Suggest that they choose an activity that is routine for them and try to identify problems in that activity. For example: eating breakfast, going grocery shopping, washing their dog, taking a hike, and so forth.

   Activity Mapping

   1) Pre-activity: Describes what is done before the activity
   ↓
   2) Activity: Explains what is involved in the activity
   ↓
   3) Post-activity: Includes what is involved after the activity
   ↓
   4) Assessment: Involves how one knows if the activity has been successful

5. Now, have students add additional design problems to their list and be as specific as they can. Remind them of the question: "What problems would you like to solve or what improvements would you like to make on a current product?" Encourage the young designers to dream!

Refining the List

1. Ask the group to come up with some questions to help each other narrow down their list of design opportunities to select a few to focus on. Working in pairs, students should ask each other probing questions to help clarify what the need, problem, or improvement is and which holds the most promise for solutions.

8A: Revisit (continued)

Example probing questions are:

- What about this product is frustrating?
- Do you know of any similar products that have been adapted from this product?
- What would you like to see this product do?
- What part of the product would need to be changed, the whole thing or one part?
- Would other people benefit from this improvement? If so, who?

2. Another option is to have students place their lists of design opportunities on their desks and walk around to look at everyone's list. Students may read the lists and write comments next to the problems that their peers addressed. They can then use the comments to help them narrow down their list.

3. Each student should be ready to select the top three design opportunity choices.

4. Ask them to consider where they could gather the most data about other people's use and impressions of the problem or improvement that they have identified.

Wrap Up

Students share their top three design opportunities with the whole group. Then, they discuss where they could gather the most data about the problems and improvements that they identified.

Follow With

In *8B: Research* and *8C: Refine*, students learn how to conduct a survey to gather more data about problems and improvements.

Revisit

Worksheet: Session 8, Activity A

It is now time to think about your end-of-year exhibition. This will give you the opportunity to show how hard you have worked and to celebrate your accomplishments. Listen to what other students and parents/visitors say when they visit you at your stand to look at your project. This will provide you with useful information on your prototype and presentation skills. You may then like to do some further work on your project and enter it into the Young Scientist and Technology Exhibition, which is held in the RDS in Dublin each January.

In Session 2 you listed 10 problems you would like to solve. It is now time to REVISIT that list, carry out RESEARCH and REFINE your ideas. You can add some new ideas if you like.

Remember the first step of the design process:

Design Process Step 1. Identify a Design Opportunity

Working with a partner or two other students sort through your lists and identify ten design opportunities.

1. ____________________________________
2. ____________________________________
3. ____________________________________
4. ____________________________________
5. ____________________________________
6. ____________________________________
7. ____________________________________
8. ____________________________________
9. ____________________________________
10. ____________________________________

8A Worksheet: Revisit (continued)

Review the list with your partner/s and select your three favourites based on your discussion and your interest in pursuing the problem.

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

Where could you gather data about other people's uses and impressions of the problems and improvements that you have identified?

____

____

____

____

____

Session 8, Activity B

Research

In This Session:

A Revisit
(40 mins)
▶ Student Worksheet
▶ Student Discussion + H/W

B Research
(40 mins)
▶ Student Worksheet
▶ Student Discussion + H/W

C Refine
(40 mins)
▶ Student Worksheet + H/W

D SCAMPER to Solutions
(H/W)
▶ Student Worksheet

Goal

Students gather data about design opportunities to help them select a design project.

Outcome

Students will collect data about design problems and choose one to solve with a design project.

Description

Students conduct a survey with a variety of people and observe how people interact with products to help them clarify one design opportunity. This one design opportunity may change as ideas are refined in an iterative design process.

Supplies

Clipboard for surveying (optional)

Preparation

Review students' lists and ideas for data collection.

As homework students might visit the local shop or shopping centre, the hardware store, and so forth.

Students should have their lists from the previous activity, *8A: Revisit*.

Procedures

Conducting the Survey

In this activity, students focus on Step 2 of the design process: Research the Design Opportunity. This is where they gather lots of information about the nature of the problem. They find out about the user, the user's preferences, and collect data about the context and realities of the user's life, environment, and behaviors. In short, market research. The idea is for students to get feedback on the design opportunity before refining their choice even further.

8B: Research (continued)

2. Have students prepare survey questions. The questions should help them gather data about the problem and the user. Some sample questions are given in the student worksheet.

3. Now have them make a list of things that they will be observing (note: in some cases, they may not be observable—especially if students have come up with something completely novel). For example:

    - Who is looking at this product?
    - Are people purchasing this product?
    - How much is this product?
    - How is this product made?

4. Ask them to come up with a script for an introduction, explaining who they are, what they are doing, and the purpose of their survey, and requesting a few minutes of someone's time.

5. They can practice their script and questions in pairs.

6. They are now ready to conduct their survey. They should try to survey about 10 people.

Research

Worksheet: Session 8, Activity B

You will now have a chance by surveying people from the general public to do some market research on the three design challenges you chose in the previous activity. Gathering data in this way will help you decide on one design opportunity.

Design Process Step 2. Research the Design Opportunity

Writing a Survey
Writing a survey is harder than it appears. Remember to include a brief introduction explaining what you are doing.

Survey Questions
Questions should be as simple as possible. Remember not to include too many questions and that you are looking for short answers.

Sample questions you might like to ask

1. Do you use this product?

Product 1 yes ❑ no ❑
Product 2 yes ❑ no ❑
Product 3 yes ❑ no ❑

2. What do you not like about this product?

Product 1 ______________________________

Product 2 ______________________________

Product 3 ______________________________

3. Would you use this product if (describe change)?

Product 1 yes ❑ no ❑
Product 2 yes ❑ no ❑
Product 3 yes ❑ no ❑

When you have written your survey you should test it on other members of the class. This will help you identify any questions that might need changing.

Session 8, Activity C

Refine

In This Session:

A **Revisit** (40 mins)
- Student Worksheet
- Student Discussion + H/W

B **Research** (40 mins)
- Student Worksheet
- Student Discussion + H/W

C **Refine** (40 mins)
- Student Worksheet + H/W

D **SCAMPER to Solutions** (H/W)
- Student Worksheet

Narrowing the Design Project

1. Back in class with their market research in hand, students should spend time sorting through the data that they collected. In doing so, their goal is to narrow their list of design opportunities. They should think about which problem would be most possible for them to work on. They can begin to do this by listing the pros and cons for each possibility based on their research. Remind them that they are still focusing on problems; however, it's natural to have ideas for solutions "popping up" and this may guide them as they narrow their focus.

2. As they narrow down their choices, remind them to consider what aspect of a particular design they would like to see improved or developed, since they could decide to choose the whole product or a part of the product.

3. In small groups, have them share their lists of pros and cons and get feedback from each other to help them choose one design opportunity.

4. They are now ready to make a decision. Encourage them to make a decision by selecting one or two problems that are most compelling to them. Explain that their decisions are not permanent; they may find that they change their design choice a few times throughout this process. Do not force or rush the process!

Developing the Problem Statement

1. Now that they have narrowed their list to one design opportunity, they need to formulate a "problem statement" that expresses the "heart" of the situation.

2. Discuss the features of a problem statement for example using the toothpaste cap example:

    - Begins with a clear, concise, well-supported statement of the problem to be overcome.

      The toothpaste screw cap poses many problems for people. When taken off, the cap may be easily dropped into the sink drain, on the dirty floor, or even into the toilet.

8C: Refine (continued)

- Includes data collected during the survey/observation in order to better illustrate the problem.
  After observing my family members using toothpaste with a screw cap, I observed my younger sister leaving the cap off and on the sink, my dad putting the cap down on the sink and leaving toothpaste behind after putting the cap back on, and my mom dropping the cap on the floor. When talking to people about their use of the screw cap, they reported similar problems.

- Establishes the importance and significance of this problem.
  These problems with the screw cap seem to be widespread. With a little innovation, this problem can be solved.

- Describes the target population.
  *While I realized that everyone uses toothpaste, I also observed that it is primarily women who purchase the toothpaste. Therefore, my product design wi*ll need to appeal to women in particular.

3. Tell them to write the problem clearly so that it could be explained to anyone.

Wrap Up
Have students discuss how easy or difficult it was to narrow their lists and why this was the case.

Follow With
In *8D: SCAMPER To Solutions*, students begin to consider solutions to their problems.

Refine the Problem

Worksheet: Session 8, Activity C

Review the results of your survey

Using the survey results write the pros and cons next to each of the three design challenges.

Design Challenge	Pros	Cons
1		
2		
3		

Select One design opportunity to address

Develop a Problem Statement

Write a clear problem statement. This is intended for someone who knows nothing about this problem. The problem statement should:

- Begin with a clear, concise, well-supported statement of the problem to be overcome
- Include data collected during the survey/observation in order to better illustrate the problem
- Establish the importance and significance of the problem
- Describe the target population

Session 8, Activity D

Scamper to Solutions

In This Session:

Goal
As a homework exercise students brainstorm possible solutions to their design project.

Outcome
Students generate several solutions for their design project.

Description
Using the SCAMPER process, students develop a list of possible solutions to their problem or improvement.

Supplies
None

Procedures
SCAMPER

This activity is Step 3 of the design process: Brainstorm Possible Solutions To The Problem. Now that students have one design project in mind, they are ready to consider solutions to their problem. In doing so, they should first consider what the desired outcome is. That is, how will they know when the problem is solved? The goal of this exercise is to have them come up with five solutions to their design challenge. This is similar to what they did in the potato masher in *2B Worksheet: SCAMPER and The Potato Masher.* However, now they are doing SCAMPER for their own design projects.

Ask: What is the desired outcome of the design? What do you want the product to do?

From the previous activities, students should be familiar with the creative thinking processes. Revisit the SCAMPER technique for brainstorming. Have students review SCAMPER and the SCAMPER process applied to a potato masher from *2B: SCAMPER and The Potato Masher.* SCAMPER should help them generate several ideas for solutions to their design challenge.

8D: Scamper to Solutions (continued)

Revisit Activity Mapping

1. Time permitting, students could also use Activity Mapping to help them focus and come up with solutions, *2C Worksheet: Design Opportunities are Everywhere.*

Solution Criteria

1. Now that learners have a number of ideas that can serve as possible solutions to their problem, it's time to evaluate them systematically. Have them generate a variety of criteria and analyze their solutions with the criteria. This might include such things as:

    - It is practical.
    - It can be made easily.
    - It is safe.
    - It will not cost too much to make or use.
    - It is a new idea.
    - It is not too similar to something else.
    - It addresses the problem.

2. Have students review each solution. Using the criteria, they should identify and evaluate the relative strengths and weaknesses of possible solutions.

2. Depending on which of their solutions meet the criteria, ask students to further narrow their list of solutions to three that they will investigate in greater depth.

Wrap Up
Remind students to keep careful notes of their decision-making process in their design notebooks. Have them review their notes and ensure that they are keeping clear records of their process.

Scamper to Solutions

Worksheet: Session 8, Activity D

You now need to consider possible solutions to your design project. In doing so, it is important to consider the outcome of the design - what do you want the product to do? Use SCAMPER to come up with some solutions. You do not have to use all the steps of SCAMPER

Design Process Step 3. Brainstorm Possible Solutions to the Problem

Substitute (What else can be used instead? Other ingredients? Other materials?)
Combine (Combine other materials, things, or functions.)
Adapt (Can it be used for something else?)
Minimise/Magnify (Make it bigger or smaller.)
Put to other uses (New ways to use as is? Other uses if modified? Other people or places to reach?)
Eliminate/Elaborate (Remove some part or materials, or make one section more detailed or refined.)
Reverse/Rearrange (Flip-flop some section of the item or move parts around. Interchange components? Different sequence? Turn it upside-down?)

List your design solution ideas below:

1. ____

2. ____

3. ____

4. ____

5. ____

Review your solutions, asking yourself questions such as:

- Does it address the problem?
- Is it practical?
- Can it be made easily?
- Is it safe?
- Will it cost too much to make or use?
- Is it too similar to something else?

Having answered the questions **circle the three best** solutions

Notes:

Session 9

A Solution Taking Place

In This Session:

A Sample Design Brief (40 mins)
- Student Worksheet

B My Design Brief (40 mins)
- Student Worksheet + H/W

C The User (20 mins)
- Student Worksheet

D Patents and Inventions (20 mins)
- Student Worksheet
- Student Reading + H/W

This session involves online research using computers with Internet access. It is ideal for each student to have his or her own computer to use during this session. If you do not have access to computers, try to arrange a visit to the local library where students can use computers. In this session, students plan out one of their design solutions by following Steps 4 and 5 of the design process.

The first activity of this session *9A: Sample Design Brief*, students read and discuss the parts of the design brief as a group, analyse the sample and think about writing their own. In the next activity *9B: My Design Brief*, students prepare their own design brief. In *9C: The User*, students delve in deeper into who the users of the product will be and how they will design the product to meet the user's needs. In activity *9D: Patents and Inventions*, students use the government's official patent Web site to dig into the world of patents looking for products that might be similar to their own.

Supplies
- Computers with Internet connections
- Optional: Parts catalogues

Intel Education

A Solution Taking Place

Key Concepts: Session 9

In Session 9, students concentrate on the improvement and refinement of their design solutions by writing a design brief and gathering information about inventors and inventions through the research of patents. A design brief is another formal tool written by professional designers and engineers to begin to gather and describe important details about the idea, the solution and other facts. While the design process informs the steps that students follow to develop their projects, the design brief is used to record their own ideas and guide them through the design process. In this session, students start to think about realistic aspects of their projects, such as who will be using their project. This is a perfect time to bring in mentors who assist students as they develop their projects. The use of the Internet is critical in making this research process effective. As students begin to explore the development of inventions on various Web sites, they may think of new ideas that will further refine their design solutions. Key to this session is the idea that designers and inventors take many different approaches to solving problems and the result is a wide variety of design solutions.

Key Concepts

Design brief: A written plan that identifies a problem to be solved, its criteria, and its constraints. The design brief is used to encourage thinking of all aspects of a problem before attempting a solution.

Creating a Design Brief
A design brief is the blueprint or road map for a project. Writing down ideas helps students think through the problem and their ideas for a solution. The design brief is an evolving document that can and should be changed throughout the design process. In helping students develop their design brief, it is best to encourage them to think big and not limit themselves at this stage. They should do what they can to understand the problem through observation and visualizing a solution. At this point, they may even have multiple solutions. They should not see the design brief as limiting their thinking, but rather as a place to record, track and communicate their ideas.

Students are introduced to a design brief in *9A Worksheet: Sample Design Brief*. The act of writing down ideas and plans strengthens critical thinking.

User Considerations
As students develop their projects, it is important for them to remember that not all users will be like them. In the real world, design agencies develop user profiles and usability requirements by gathering information about users. There are different strategies for this - definition and observations of different kinds of users, conducting formal usability studies, or doing surveys. They will want to understand, for example, people who are most likely to use a new product and people who are hesitant to use new products. Interviews are another means to acquire user data.

Key Concepts (continued)

This takes place through observation as well as interviews because it seems that when people are asked questions, as is typically done in market research, they may not answer honestly. there is a difference between what people say and what they do. Students begin to consider who might use their products. Developing a user persona helps them to keep in mind the end user throughout the design process. Encourage students to observe people using similar products to the one they are improving upon or creating and keep in mind the typical user as they develop their project.

A patent is granted to the inventor by a country's government and it gives the inventor the right to make, use and sell an invention for a set period of time. You can search patents at the Irish Patents Office (http://www.patentsoffice.ie/) to see if an invention has already been patented by someone else.

Gaining a patent can be a complex process. A solicitor is often sought out when applying for a patent, due to the complexity of the procedure. A patent application needs to be completed and submitted to the Irish Patents Office. A patent application consists of several parts: (1) the abstract; (2) the specification; (3) the claims; and (4) the drawings. A brief abstract summarizes the invention. The specification describes the method and process of making and using the invention. Claims conclude the specification section and legally define the boundaries of patents. The claims describe any unique features of the invention that need to be protected. The final piece of the patent application is drawings which illustrate the invention.

Trademarks protect words, names, symbols, sounds or colours that identify goods and services from those sold by others. Trademarks can be renewed indefinitely. Some trademark owners use a TM (trademark) or SM (service mark) symbol to indicate that they are claiming rights to the use of the trademark. The Nike® swoosh is a familiar trademark symbol. The ® designation is used once a trademark is registered in the Patent Office.

Copyrights provide the right to reproduce, distribute, perform, display or license original writing, music and works of art. Copyright covers the expression of ideas and not the idea itself.

Session 9, Activity A

Sample Design Brief

In This Session:

A Sample Design Brief (40 mins)
- Student Worksheet

B My Design Brief (40 mins)
- Student Worksheet + H/W

C The User (20 mins)
- Student Worksheet

D Patents and Inventions (20 mins)
- Student Worksheet
- Student Reading + H/W

Goal

Learn the contents of a design brief.

Outcome

Students learn how to write their own design brief.

Description

Group review of a sample design brief for a string bass hand holder allows students to study the contents and purpose of a design brief before writing their own. Following a short introduction on what a design brief is and what it does, students read the sample design brief. A group discussion of each part of the brief assures that students understand what they will be preparing in the next activity. They have time at the end to review their notes and share their plans for the design brief with a partner.

Supplies

None

Preparation

Review *9A Worksheet: Sample Design Brief.*

Procedures

1. Discuss students' thinking about appropriate materials for different functions in the home.

Design Brief

1. Introduce the activity as Step 4 in the design process. Write a Design Brief. Explain that they will be writing a design brief after studying a sample.

intel Education

9A: Sample Design Brief (continued)

2. Describe what a design brief is and what it does.

   What it is. A design brief is a short description of a design problem and a proposed solution. It describes the typical users and their needs, and states a proposed solution in terms of how it will solve the problem. A design brief includes a sketch or sketches of the solution. The design brief provides a planning tool for the project and is a living document that may be changed throughout the design process.

   What it does. The design brief is a way to clarify the problem that the designer-engineer is trying to solve. It doesn't provide a lot of detail about the solution but puts on paper the thinking and research about the problem to solve. Often the act of writing and communicating the problem and proposed solution helps the designer move along in the design process. The design brief also serves to introduce the idea to others for feedback.

3. Have students read *9A worksheet: Sample Design Brief.*

4. Review and discuss each section:

Wrap Up
Organize students for writing rough drafts of the design brief.

Follow With
Students write and present their own design brief in *9B: My Design Brief.*

Sample Design Brief

Worksheet : Session 9, Activity A

Design Process Step 4. Write a Design Brief

A Design Brief – What it is
A design brief contains:

- a short description of a design problem
- a proposed solution
- the profile of a typical user
- a proposed solution in terms of how it will solve the problem
- a sketch or sketches of the solution
- the basic requirements needed to produce a prototype

A Design Brief – What it does

- It helps clarify the problem that the designer/engineer is trying to solve.
- It doesn't provide a lot of detail about the solution but puts on paper the thinking and research about the problem. Often the act of writing and communicating the problem and proposed solution helps the designer move along in the design process.
- It also serves to introduce the idea to others for feedback.

Remember the design brief may be changed at any time throughout the design process.

Sample Design Brief: Bass Space (patent pending)
Erica is a *Design and Discovery* student. She has played the string bass for a few years and remembers as a beginner struggling with keeping her fingers together. This is Erica's design brief.

Describe the problem. Write a statement that focuses on what's wrong and not working. Recall the features of a problem statement

- Begins with a clear, concise, well-supported statement of the problem to be overcome.
- Includes data collected during the survey/observation in order to better illustrate the problem.
- Establishes the importance and significance of this problem.

When people start playing the string bass, most beginners cannot hold their hand correctly, preventing them from being able to play properly. As a string bass player, I have had personal experience with this and have seen other beginner string bass players also struggle with this.

Describe how the current product is used. Provide a context for the problem and explain any related solutions that resemble or relate to the problem but have failed to address the problem.

Currently, there is not a product for this. Sometimes, a string bass teacher may tell her students to tape their fingers together.

9A Worksheet: Sample Design Brief (continued)

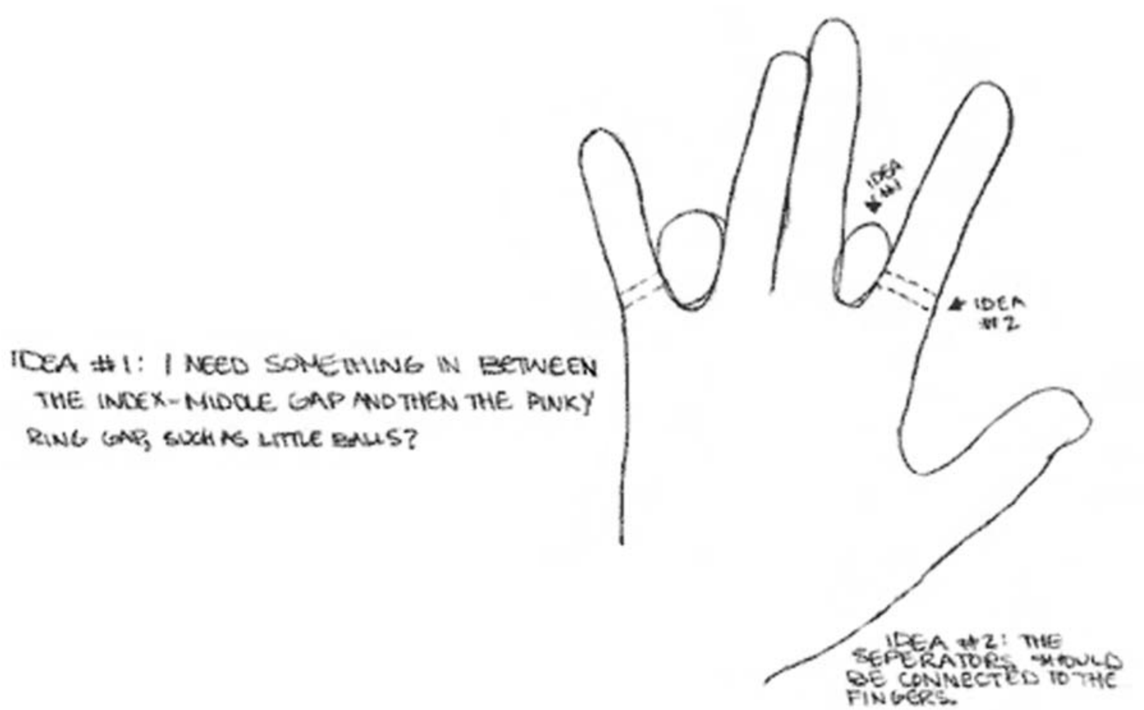
Describe a typical user (user profile). This addresses who uses the product and how their needs are or are not met. How will they benefit from a different product?

A typical user is a beginning string bass player. They struggle with holding their hand correctly and keeping their fingers in place. They will benefit from a product that helps them keep their fingers and hands in the correct form to learn to play the string bass. They will be much more comfortable and able to practise for longer periods of time.

Propose a solution: Describe how it will work, and how it solves the problem. Explain the features.

I'm not sure what type of material I would use, but the Bass Space would allow the player to keep her two middle fingers together and separate from her pointer finger and pinky. It would be adjustable in size depending on the size of the person's hands.

Draw a quick sketch of your ideas. This is a rough sketch and can include drawings of different angles of the solution.



Describe the basic requirements that will best suit the proposed product. For example, this describes the quality (for example: flexible or sturdy) and the type of materials (for example: metal or plastic).

The material needs to be stiff yet flexible to allow hand movement, it cannot break easily, it has to be adjustable for different size hands, will need to slide on and off easily, must be low on the fingers to allow the fingers to bend, must be cost efficient, must hold hand correctly, and it must be comfortable.

Session 9, Activity B

My Design Brief

In This Session:

A Sample Design Brief (40 mins)
- Student Worksheet

B **My Design Brief (40 mins)**
- Student Worksheet + H/W

C The User (20 mins)
- Student Worksheet

D Patents and Inventions (20 mins)
- Student Worksheet
- Student Reading + H/W

Goal
Refine and describe a problem to solve and a proposed solution.

Outcome
Each student introduces his or her idea by completing and presenting a design brief.

Description
Students use this time to prepare a draft of the design brief and draw rough sketches in their design journals. They write a final draft and draw sketches on the design brief worksheet or in their journal. Each student uses the design brief to give a short presentation about the problem and proposed idea.

Supplies
None

Preparation
None

Procedures

1. Students work on their own design briefs.
2. Allow enough time for presentations and wrap up. Announce a deadline for the final draft and sketches.
3. Students should plan a 2-minute presentation of their problem and the proposed solution.
   - State the problem and describe the needs of the user.
   - Describe the solution.

Wrap Up
Have students reflect and write about: In what ways did writing my design brief help me with a solution?

Follow With
Activity 9C: The User helps students think about the person(s) for whom they are designing their projects.

Intel Education

My Design Brief

Worksheet: Session 9, Activity B

Writing your own design brief should help you clarify your ideas and think about them systematically. This is a working document: It will be your road map as you develop your ideas.

Describe the problem. Write a statement that focuses on what's wrong and not working. Recall the features of a problem statement:

- Begins with a clear, concise, well-supported statement of the problem to be overcome
- Includes data collected during the survey/observation in order to better illustrate the problem.
- Establishes the importance and significance of the problem

____

____

____

____

Describe how the current product is used. Provide a context for the problem and explain any related solutions that resemble or relate to the problem but have failed to address the problem.

____

____

____

Describe a typical user (user profile). This addresses who uses the product and how their needs are or are not met. How will they benefit from a different product?

____

____

____

9B Worksheet: My Design Brief (continued)

Propose a solution: Describe how it will work, and how it solves the problem. Explain the features.

____

____

____

____

Draw a quick sketch of your ideas. This is a rough sketch and can include drawings of different angles of the solution.

Describe the basic requirements that will best suit the proposed product. This describes the quality (for example: flexible or sturdy), and the type of materials (for example: metal or plastic).

____

____

____

____

Session 9, Activity C

The User

In This Session:

A Sample Design Brief (40 mins)
- Student Worksheet

B My Design Brief (40 mins)
- Student Worksheet + H/W

C **The User (20 mins)**
- **Student Worksheet**

D Patents and Inventions (20 mins)
- Student Worksheet
- Student Reading + H/W

Goal
Learn how to define the user of the product.

Outcome
Identify a typical user of the product in order to help focus the development of the product.

Description
Students look at a variety of familiar objects from the perspective of a typical user. They learn how to identify users of products and ultimately define their user base for their projects.

Supplies
None

Preparation
Bring in a variety of familiar objects that appeal to different ages and genders. This might include toys (for different ages), kitchen items, tools, and so forth.

Procedures
Show the group one of the familiar objects. Ask them:
Who typically uses this product?
What is their gender? Age? Experience with this type of product?
How is the product designed for this type of person (user)?
Where does the user use this product?
What motivates the user to use it?
Now, describe a scenario of someone using this product:
Give the person an identity (name, age, gender, occupation, etc.).
Describe the setting in which the person is using the product.
Explain what the person's goals are. What do they want to get out of this experience?
Tell how they use this product.
Summarize how their goals are met by this product.
Follow the first procedure for a few other familiar objects.

Intel Education

The User (continued)

Ask students how this exercise can help them with their projects. Creating an identity of the user helps the experience of designing something become more concrete. Without narrowly defining the user, a product that tries to please too many different types of people will most likely fail.
Now ask students to consider their own projects and who they see as the typical user. They should come up with a user scenario on their handouts.

Wrap Up
Students can share their user scenarios in small groups and get feedback from each other.

Follow With
Activity 9D Patents and Inventions

The User

Worksheet: Session 9, Activity C

Now that you have a particular design idea in mind it is time to concentrate on the improvement and refinement of your design solution by gathering information about a typical user. It is also a good idea at this stage to look at other inventions and to find out about patenting your idea. This will help you see that there are many different approaches to solving problems and the result is often a variety of design solutions.

Design Process Step 5. Research Your Solution.

The User

Think about your product area. Consider the following questions.

- Who will use this product?

  ____

- What is the person's gender? Age? Experience with this type of product?

  ____

- Where will they use this product?

  ____

- Why will they use this product?

  ____

- What will they be doing to operate or use this product?

  ____

Using the above information, describe one person who will be the user. What are there characteristics and the scenario in which they will use the product? You may include a drawing of the person using the product if that helps.

____

____

What considerations will you need to keep in mind when you design the product to meet the needs of the user?

____

Session 9, Activity D

Patents and Inventions

In This Session:

A Sample Design Brief (40 mins)
- Student Worksheet

B My Design Brief (40 mins)
- Student Worksheet + H/W

C The User (20 mins)
- Student Worksheet

D **Patents and Inventions (20 mins)**
- Student Worksheet
- Student Reading + H/W

Goal

Use research on similar design solutions to refine ideas.

Outcome

Solutions are further refined or revised after research.

Description

In this activity, students explore Patent Web sites to find and learn from patents similar to their idea.

Supplies

Computers with Internet connections

Preparation

Ideally, each student will have a computer to work on for this activity. If computers are not available, you may print out suggested examples.

Procedures

Patent Scavenger Hunt

1. Begin by asking students to go on a short scavenger hunt around the room. Have them look at manufactured objects (furnishings, electronic devices, appliances) in the room and see if they have a manufacturer's label on them with a patent number (or the words Patent Pending.)

2. Discuss the purpose of patents. At the very basic level, according to the Patent Office, "A patent is a grant issued by the governments giving inventors the right to exclude all others from making, using, or selling their inventions.The patent system protects inventors and records new inventions.

Patent Search for an Idea or a Problem

1. A patent search can provide useful information at any point in the design process. Begin by having students learn how to search Patent and Trademark Web sites.

2. Note: If you do not have computer access for all students, it is suggested that you print a few examples of patents (the first page) and the images.

intel Education

9D: Patents and Inventions (continued)

Patent Search for Your Design Solutions

1. Now that students are familiar with how to do a patent search, they can conduct a search for their own design solutions. This process helps them to see if anyone else thought of an idea like theirs, and if so, how those solutions are similar to or different from their ideas.

2. To begin, they will need to come up with key words to search.

3. Once they conduct a search and find the results, they can explore each separate patent to find out about other inventors' approaches to problems and see that there are quite a variety of engineering solutions, materials, and design ideas for the same problem!

4. As they conduct the search, they should ask themselves the following questions:

How do other inventors view the nature of the problem?

a. In looking at the various patents that are similar, are the inventors designing for the same "user"? How do the different solutions show that inventors may consider different aspects of a user's life, environment, and behaviors?
b. What materials have other inventors used to address the problem? How have others manufactured their inventions?
c. Have other inventors' solutions caused unintended problems, like waste due to packaging?
d. What do other inventors' sketches/designs look like? What are the similarities/differences in the design solutions?
e. What components have other people used? Have they considered similar or very different components for their design solutions? Have they used the same essential components but arranged them in a different way? Do different parts of the various inventions captivate you?
f. How can you recombine their ideas to improve on the solution to the original problem?

9D: Patents and Inventions (continued)

Students may find themselves stimulated by the ideas on the patent site. They may want to use others' ideas to improve upon their own design ideas and solutions. Encourage them to mingle their ideas and see what new and creative ideas they can come up with.

Wrap Up
Students should be keeping detailed records in their design notebooks; be sure that they record any changes and additions throughout the process and date everything!

Have students read 9D Reading: Great Inventors and try looking up the patents for some of these inventions.

Patents and Inventions

Worksheet: Session 9, Activity D

In this activity, you will explore the patent website to find and learn from patents similar to your idea. You will also explore invention Web sites for inspiration and ideas for your project.

Remember you should be keeping detailed records in your design notebook. Be sure to record any changes and additions throughout the process and date everything!

Patent Search for a Problem or Idea
Visit the patent website http://www.patentsoffice.ie/

Patent Search for Your Design Solutions
Now that you are familiar with patents, you can use the patent site for your own research on design solutions. This process will help you to see if anyone else thought of an idea like yours and if so, how those solutions are similar to or different from your ideas. It should also help you plan your solution. If you find that your solution has already been patented or that there is another idea that is better than yours, you may need to take a few steps back and revisit your other problems and/or solutions.

How to do a search:

1. Come up with key words to search.
2. Once you have some results, explore each separate patent to find out about other inventors' approaches to problems and see that there are quite a variety of engineering solutions, materials and design ideas to the same problem!

Ask yourself the following questions:

- How do other inventors view the nature of the problem?
- In looking at the various patents that are similar, are the inventors designing for the same "user"?
- What materials have other inventors used to address the problem? How have others manufactured their inventions?
- Have other inventors' solutions caused unintended problems, like waste due to packaging?
- What do other inventors' sketches/designs look like? What are the similarities/differences in the design solutions?
- What components have other people used? Have they considered similar or very different components for their design solutions? Have they used the same essential components but arranged them in a different way?
- Do different parts of the various inventions captivate you? How can you recombine their ideas to improve on the solution to the original problem?

Worksheet: Patents and Inventions (continued)

Other useful Websites that you might like to check out include:

- Rolex* Awards for Enterprise: http://www.rolexawards.com*
- US Inventors Hall of Fame*: http://www.invent.org/index.asp*
- Invention Facts and Myths: http://www.ideafinder.com/history/of_inventions.htm*.
- HowStuffWorks: http://www.howstuffworks.com*
- Timeline of Inventions: http:www.cbc4kids.cbc.ca/general/the-lab/history-of-invention/default.html*

Great Inventors

Reading: Session 9, Activity D

Margaret Knight, patent #220,925 (1879) Paper Bag Machine
Knight, the "female Edison," invented a square-bottomed paper bag machine that allowed folded bags to stand open by themselves. She received 26 more patents, including shoe manufacturing methods and improvements to rotary engines.

Harriet Williams Strong, patent # 374,378 (1887), Dam and Reservoir Construction
Strong, a widow with four children, registered patents on flood control/water storage dams and irrigation systems. The dams in her system used the pressure of the water itself in a lower dam to structurally support the higher dam. She became known as "The Walnut Queen" as her system was widely adopted, especially for irrigating walnut groves.

Elisha Gray and Alexander Graham Bell, patent #174,465 (1876) Telegraphy.
In the 1870s, two inventors Elisha Gray and Alexander Graham Bell both independently designed devices that could transmit speech electrically (the telephone). Both men rushed their respective designs to the patent office within hours of each other, Alexander Graham Bell patented his telephone first. Elisha Gray and Alexander Graham Bell entered into a famous legal battle over the invention of the telephone, which Bell won.

Orville and Wilbur Wright, patent #821,393 (1906) Flying Machine.
In 1900, the Wright brothers, Orville and Wilbur, successfully tested their new 50-pound biplane glider with its 17-foot wingspan and wing-warping mechanism at Kitty Hawk, in both unmanned and piloted flights. During 1902, the brothers flew numerous test glides using their new glider. After months of studying how propellers work the Wright Brothers designed a motor and a new aircraft sturdy enough to accommodate the motor's weight and vibrations. The craft weighed 700 pounds and came to be known as the Flyer.

Janet L. Rideout and Martha H. St. Clair, patent #4,724,232 (1988), Treatment of Human Viral Infections.
Rideout, a chemist who worked with retro-virus specialist St. Clair and three other colleagues, discovered that the AZT compound was effective in combating the AIDS virus.

Garrett Augustus Morgan, patent #1,475,824 (1922) Traffic Signal.
Morgan was an African-American businessman and inventor. Among his inventions was an early traffic signal, that greatly improved safety on America's streets and roadways. Indeed, Morgan's technology was the basis for modern traffic signal systems and was an early example of what we know today as Intelligent Transportation Systems.

Notes:

Making, Modelling and Materializing

Session 10

Project Analysis and Planning For Models

In This Session:

A Project Analysis (40 mins)
- Student Worksheet

B Conceptual Drawing: Thinking on Paper (40 mins)
- Student Worksheet

C Checking in on the Design Process (20 mins)
- Student Worksheet

D Materials and Modelling Plans (20 mins + H/W)
- Student Worksheet
- Student Reading

This session begins with a project analysis to examine the cost, safety and practicality of each design solution. The session also helps students develop a better understanding of the visual aspects of their project as they make detailed drawings of their ideas. Having checked their progress they then look at the materials needed to build their model.

In the first activity, Activity 10A: Project Analysis, students look at whether or not their proposed solution is feasible. Looking at aspects such as cost, durability and safety may lead to further changes.

In Activity 10B: Conceptual Drawing: Thinking on Paper, students learn how drawing helps the thinking process. Having made a series of conceptual drawings in their design notebooks they can now better visualise their design and have an idea of what is needed to complete the project.

In Activity 10C: Checking in on the Design Process, students look at a checklist of steps that follow the design process to determine how far they've come. Looking at the remaining steps and referring to the Design and Discovery Planner will give them an idea of what they have got to do in the time remaining.

In the final activity, 10D, students have time in class and at home to decide on, and check the availability of, the materials they need to build their model.

10: Project Analysis and Planning For Models (continued)

Supplies

A variety of materials to build models.

Supplies for Structure

- Foam (Styrofoam* in sheets and several shapes, including foam tubes for pipe insulation)
- Foam core board
- Balsa wood (sheets and pre-cut strips from craft supply stores)
- Modeling clay
- Aluminum foil
- Pipe cleaners and plastic straws
- Cardboard (tubes, boxes of all sizes, flat pieces)
- Paper (including poster board or card stock weights
- Lego* set
- Dowels, bamboo skewers
- Wheels

Other Optional Structural supplies

- Recyclable materials such as wine corks, aluminum soda cans, bubble wrap, packaging and twist ties

Parts and Materials To Connect Things

- String
- Wire
- Rubber bands
- Rubber tubing
- Tape (duct, masking, packaging, and electrical)
- Glues (epoxy, superglue, glue sticks, glues for hot glue gun and rubber cement)
- Hinges
- Nuts and bolts, washers, assorted screws
- Nails, thumbtacks

Tools

- Several sets of each: pliers, saw, hammer, screwdriver, hot glue gun, tin snips, scissors, Swiss Army knife, measuring tape, stackable measuring cups and spoons.

Project Analysis and Planning For Models

Key Concepts

A key component of the design process is the making of sketches and diagrams to clarify their ideas. Many products have come about because of "napkin drafting", a cruder and more simplistic way to communicate ideas. Encourage students to doodle, sketch and make diagrams before the actual construction occurs. This session concentrates on using elements of mechanical drawing to show the students how the visualisation of a project can help to refine the needs of the design.

Although computers are usually used nowadays to produce mechanical drawings, hand drawings of the design are still the most widely used communication tool in the engineering community, especially in the revision stage. The primary reason for this is because drawings often serve as documentation of requirements. They are used to produce quotes, determine manufacturing methods or processes and inspect parts to ensure they meet the requirements defined within the drawings. Making a readable diagram ensures that the design team members can look at it and understand what is required.

Drawing the design is an important step in refining the project and identifying some issues with the design. It is a good idea to stress to the students that if they change something to get around an issue that they should record in their design notebooks what the issue was and how they changed the design.

Drawing Methods
This session serves as an introduction to basic drawing techniques. Students should come to understand that showing their project from all angles and with component pars will help them to identify potential problems and to refine the project without having to build it first.

More about Conceptual Drawing
Lo, Jack. The Patent Drawing Book. CA:Nolo Press, 1997.
Walker, J.R. Exploring Drafting. Tinley Park, IL: Goodheart-Wilcox, 1996

Session 10, Activity A

Project Analysis

In This Session:

Goal

To carefully examine solution ideas.

Description

Students review their solution and consider the feasibility from different angles such as safety, cost, and durability. They get feedback from other people about their solution.

Before Going Home

Tell students that they need to carefully examine their solution before proceeding to the next steps. They should be sure that their solution is feasible. It is not too late to revisit the other problems and/or solutions from the earlier sessions if they come across stumbling blocks. Encourage them to talk to as many people as possible about their idea. They will need to do testing throughout their project development to ensure that their project is safe, durable, and works the way they want it to.

Next Day

Students should be prepared to check in with the teacher before moving ahead.

Project analysis

Worksheet: Session 10 Activity A

Now that you have narrowed down your design solution, you are ready for Step 6 of the design process. You need to do testing throughout your project development to ensure that your project is safe, durable, and works the way you want it to. It is also necessary to analyse the solution for cost, safety and other implications of the idea.

Design Process Step 6. Refine Your Solution.
Before you continue give your design project more thought and answer the following questions about your design solution.

Is my idea practical? If so, how?

Can it be made easily? How?

Is it as simple as possible? Explain.

Is it safe? How?

10A Worksheet: Project Analysis (continued)

Is my project durable? Will it withstand use, or will it break easily? Explain.

Will it cost too much to make or use? Explain.

Is my idea really new? Explain.

Is my idea similar to something else? Explain.

Will people really use my product? How?

Session 10, Activity B

Conceptual Drawing: Thinking on Paper

In This Session:

A Project Analysis (40 mins)
▶ Student Worksheet

B **Conceptual Drawing: Thinking on Paper (40 mins)**
▶ Student Worksheet

C Checking in on the Design Process (20 mins)
▶ Student Worksheet

D Materials and Modelling Plans (20 mins + H/W)
▶ Student Worksheet
▶ Student Reading

Goal

Learn how conceptual drawings help fine-tune a design.

Outcome

Learners make conceptual drawings of their projects that show all the parts of the design.

Description

Student designers take their project another step farther along the design process as they make conceptual drawings of their project ideas. They learn that the drawing process is a helpful part of refining a design concept, bringing to light practical concerns that need to be resolved, such as how component parts fit together. Drawing from a variety of perspectives helps illustrate all the features of a design and helps the designer communicate ideas to others.

Supplies

None

Preparation

None

Procedures

Imagine…

1. Start with a visual imagery activity. Ask designers to close their eyes or rest their heads on their arms and try to picture their project. Speak slowly with thinking time between the questions and statements.

    - Try to get a picture of your project in your mind. Can you see it?
    - Try to picture the user using the product. Can you picture the device doing its job?
    - Imagine its size. How big is it?
    - Can you picture the materials it's made of?
    - How about the parts? Try to imagine each of them. Imagine one part connecting to another. Can you see how they work together?

10B: Conceptual Drawing: Thinking on Paper (continued)

2. Ask students to look up and talk about their ability to visualize their design. Ask how knowing what it looks like helps a person design a product (knowing the end result makes it easier to design; it's a way of refining and improving a design; lets the person look at parts in relation to the whole; conceptual and practical problems that need work will become evident).

Drawing Basics

1. Discuss how that, in addition to drawings made along the way, final drawings are made, too, before a product can go into production. Why? Drawings are needed if the designer applies for a patent; also, before the product is manufactured, drawings aid communication between the designers, engineers, materials people, and the manufacturer.

2. Discuss how seeing the object as a set of shapes is important to sketching ideas. If you know how to draw each of the shapes, then drawing the object is easier. Explain that designers show an object from several views. Have them look at the first drawing on the worksheet and discuss what the different views show about the object. Tell students that drawing their project might involve two or three drawings, one of each unique side, and maybe the inner workings as well. They may want to label parts and use arrows to show how parts move.

3. For the second set of drawings, ask students to try to match the objects shown in 3-D on the top row in their front, side and top views. *(answers: A=3, B=2, C=1,D=4, E=9, F=8, G=5, H=6, and I=7)*

4. Ask students if they recognize the next set of drawings *(different views of the crankshaft toy.)* Can they tell what views they are seeing? Have them label each figure with its viewpoint: top, interior, and side. Each drawing helps show different aspects of the device.

Begin Drawing

1. Start students on drawing a series of sketches of their design in their design notebooks. The first sketches will help them think through their design; others will be attempts at showing it as they see it in their mind's eye. Suggest that they may want to start with the most obvious features of the design and then move toward the ones that have not been resolved. Labels, notes, and arrows showing the motion of moving parts are helpful.

10B: Conceptual Drawing: Thinking on Paper (continued)

2. Encourage students to draw repeatedly and not worry about making a perfect rendering—this is a thinking step, and the successive drawings are a helpful record of their thinking process. Remind them to draw the device from top, side and front views, and even an interior cutaway view if it is helpful.

3. After 10 or 15 minutes of drawing, ask students to pause for a moment, and encourage them to talk about their efforts. Ask them to recommend tricks and tips they are finding that might be helpful to their fellow drafters—their suggestions can be really encouraging at this stage. Remind students to draw their design from all sides, and draw each view large enough to label parts and motion, and then have them continue.

Wrap Up
Have students talk about their drawings and show them to one another. What do they like about them? What new design considerations came up as a result of drawing? Is there a drawing technique they can recommend? The next step will be to model their design, and having a strong image of it will be helpful. Suggest that students continue drawing and refining their ideas before the next session.

Also suggest that students may want to make other visual representations of their ideas such as collages.

Follow With
Session 10C, *Checking in on the Design Process.*

Conceptual Drawing: Thinking on Paper

Worksheet: Session 10, Activity B

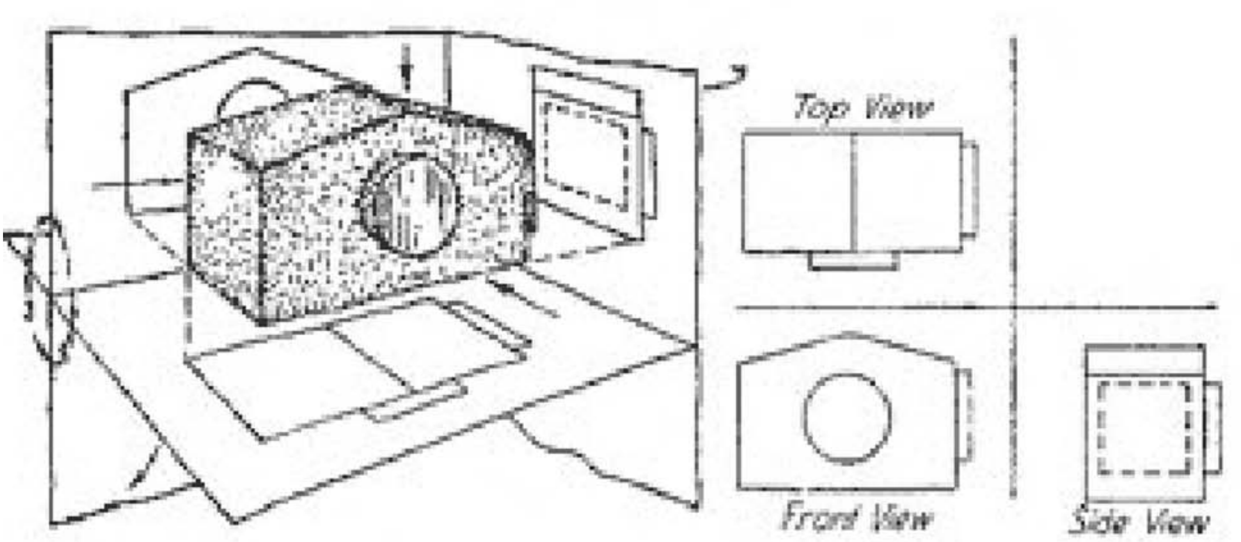
Drawing From All Sides

Drawing your ideas can help you visualise your plan and will be very useful when you make your model. You may find it very useful to draw the different components and parts of your project from different perspectives. You will probably have several drawings of your project as your ideas evolve.

Design Process Step 7. Prepare Design Requirements and Conceptual Drawings.

Example of Conceptual Drawing

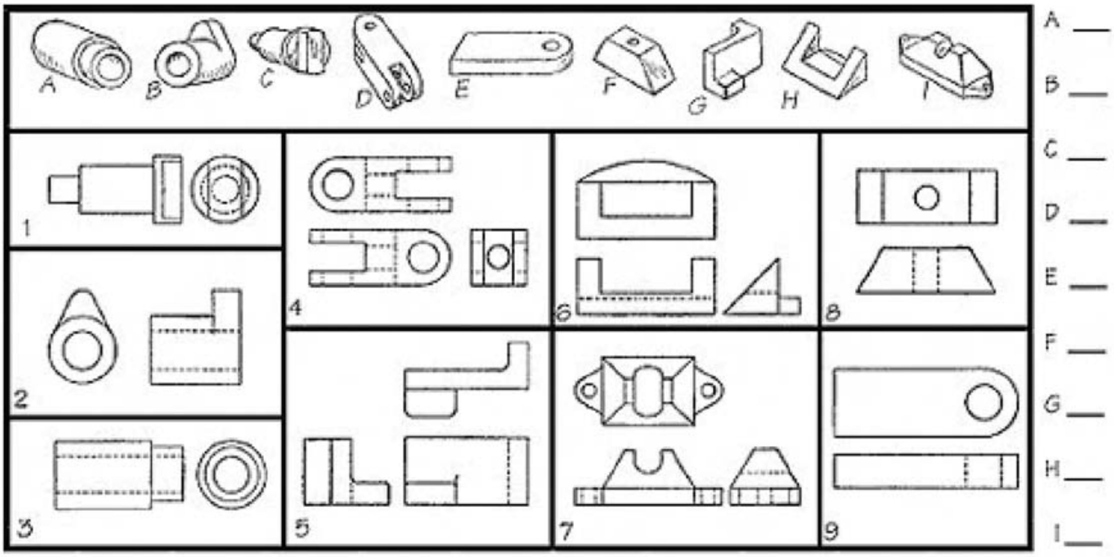
Compare the 3-D drawing of the object below to the three views of the object on the right.



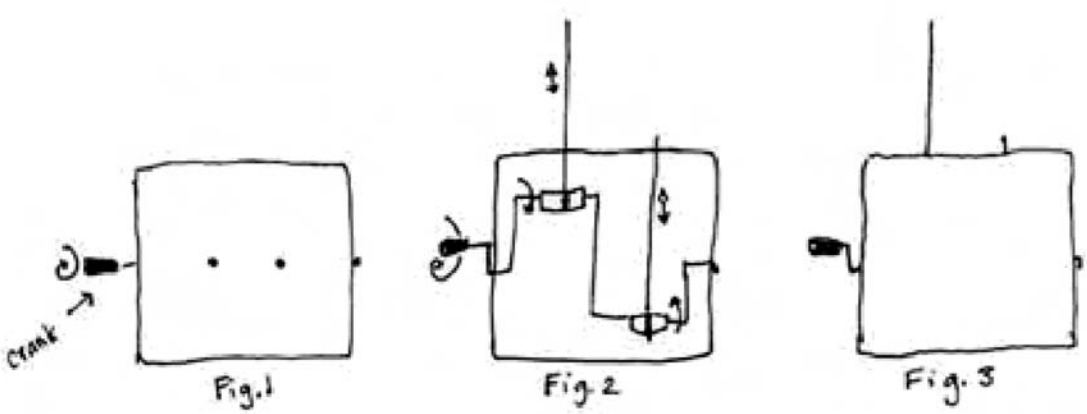
What do the three views show you about the object that you didn't know about the 3-D version?

10B Worksheet: Conceptual Drawing: Thinking on paper (continued)

2. Match the object in the top row with its orthographic sketch.



3. What object is shown here? Label the different figures: interior, top and side.



Now You Try

In your design notebook try your hand at conceptual drawings. Be sure to draw different views as well as individual drawings of the components and parts. Make lots of drawings. Make them large enough to label components and show the direction of any movement that may be appropriate to your design. A video on the Bass Hand project and other project examples can be found at www.intel.com/education/design/resources/project_examples.htm

Session 10, Activity C

Checking in on the Design Process

In This Session:

Goal

Understand the design project timeline.

Outcome

Students know where they are and what comes next on their design project.

Description

Students review a checklist for their design project and look ahead to what they will be doing. It is not a direct and linear progression through the series of steps. The steps may be repeated, and there may be small cycles between some of the steps. While they see that checklist steps follow the design process, students also discuss the non-linear nature of design.

Supplies

None

Preparation

None

Procedures

1. Introduce the session by asking students to think about where they are with their project—closer to the beginning, or to the end? Somewhere near the middle? How can they tell? Introduce the checklist worksheet as an organizer for the work they have done and will be doing in order to complete the design project—a refined working prototype.

2. Discuss the steps in the checklist and point out that while the checklist follows the design process, the design process is not linear with one step always following another. Some steps are revisited time and again; others cause the designer to change direction. The process changes as the designer's ideas change.

3. Review the schedule. Refer to the *Design and Discovery* Planner. Discuss goals and work time available in and out of class time.

intel Education

10C: Checking in on the Design Process (continued)

4. Allow time for students to review their progress, complete the checklist, and discuss any questions that come up.

NOTE
In the Teacher Guide and the Student Booklet the entire 10 steps of the design process are mapped out. While emphasising the importance of, and the difference between, a model and a prototype, you may decide, depending on time, facilities and materials available, that the student only needs to build either a model or a prototype. This would allow more time (approx. 7 x 40 minutes) for planning, construction and evaluation.

Models: Models can be visual representations of a total design that is nonfunctional. They can represent some aspect (form or function) of a specific component.
Prototypes: Prototypes tend to demonstrate some aspect of the design as a whole, either its form, function or both.

Wrap Up

Discuss any questions about the design process and review expectations for the project work ahead.

Checking in on the Design Process

Worksheet: Session 10, Activity C

The Design Process: Getting From "Think" To "Thing"

The checklist below is adapted from the design process steps. This is a tool to keep you organised and thinking about where you have been and where you want to go. It would also be a good idea, at this stage, to look at the planner at the beginning of the module to check how much time you have left to work on your project before the end-of-year exhibition.

1. **Identify a design opportunity. (Session 8)**
   - ☐ Identified about 10 design opportunities (needs, problems, or cool things to design).
   - ☐ Narrowed the list of opportunities to three for further research.

2. **Research the design opportunity. (Session 8)**
   - ☐ Refined my design opportunities with interviews and other data-gathering research.
   - ☐ Selected one design opportunity to address.
   - ☐ Wrote a problem statement to clarify and explain to anyone what I will solve with a design solution.

3. **Brainstorm possible solutions to the problem. (Session 8)**
   - ☐ Expanded my possible solutions using SCAMPER and other research.
   - ☐ Evaluated my solutions using criteria that we determined.
   - ☐ Narrowed my solutions to three possibilities.
   - ☐ Began thinking about the types of materials I could use for my solutions.

4. **Write a design brief. (Session 9)**
   - ☐ Wrote a design brief with a problem statement, description of user needs, a proposed solution, and a sketch of the solution.

5. **Research your solution. (Session 9)**
   - ☐ Researched and refined my proposed solution using the U.S. Patent Office Web site and other resources.
   - ☐ Took notes and wrote down information from my research.

10C Worksheet: Checking in on the Design Process (continued)

6. Refine your solution. (Session 10)

- ☐ Interviewed experts and possible users to analyze my project for feasibility, safety, and other implications of my solution.
- ☐ Researched materials and methods that would be appropriate for constructing my project.
- ☐ Conducted a project analysis to consider any changes to my solution.

7. Prepare design requirements and conceptual drawings. (Session 10)

- ☐ Developed design requirements that focused on the needs of the user.
- ☐ Completed conceptual drawings.

8. Build models and component parts. (Sessions 10 and 11)

- ☐ Analyzed my project design for its systems, components, and parts.
- ☐ Planned models to build and what each model would test or be able to demonstrate.
- ☐ Built a model or models of components of my design.
- ☐ Developed a project plan for completing my design.

9. Build the prototype. (Session 12)

- ☐ Conducted further research, model building, and testing, as needed to complete a working prototype.
- ☐ Developed specifications.
- ☐ Completed first working prototype.
- ☐ Analyzed prototype for functional improvements.

10. Improve your solution. Test, evaluate and revise. (Session 13)

- ☐ Prioritized improvements needed and built new or revised prototype to meet priorities.
- ☐ Evaluated prototype for function, feasibility, safety, aesthetics, and other criteria.

Session 10, Activity D

Materials and Modelling Plans

Goal
Learn about available materials and plan model(s) to build.

Outcome
Know about available materials, select those useful for their needs, and plan model building.

Description
After a brief introduction to the variety of materials available for modeling, students have time to study the materials and plan what models they want to build. The materials are organized into three groups: materials for structure, materials for connections, and tools.

Supplies
A variety of materials to build models.
(See list on page 192)

Preparation

1. Gather the materials well in advance of this session. Send home information to parents and request donations of used building materials or any of the suggested recyclable items. Purchase what is not supplied or donated.

2. On the day of the session, lay out the modeling materials organized by: a) things to build with, b) things for connecting and attaching, and c) the tools.

Procedures
Planning

1. Introduce the modeling materials. Explain, demonstrate, and answer students' questions about any unusual or unfamiliar materials or tools. Build a common vocabulary as you introduce and students study the materials.

2. Plan what to model. Have students complete Worksheet Activity 10D, answering the questions in their design notebooks.

10D: Materials and Modelling Plans (continued)

3. During this planning time, students should select and manipulate different materials as they plan. Encourage them to make notes about the materials that they study: their flexibility, strength, and their suitability as a modeling material.

Wrap Up

Ensure that each student has a plan and a clear purpose for constructing at least one model.

Follow With

Activity *11A: Making Models* provides the opportunity for students to consider the structure of their projects.

Materials and Modelling Plans

Worksheet: Session 10, Activity D

In this activity, you will start to plan your model. Like anything, the more planning you do in advance, the better your chances of achieving what you want. It's best to put answers to the questions below in your design notebook.

A Model is a small but exact copy of something

1. What do you want or need a model of? (List at least three possibilities.)

____

____

____

2. For each model possibility, consider the following questions and answer them in your design notebook:

   - Is this a system or a component of your design project?
   - What will this model help you understand about your idea?
   - Will it be a small or full-scale version?

3. As you plan, you may select and manipulate different materials. Be sure to make notes about the materials that you study: their flexibility, strength, and their suitability as a modeling material. Fill out the checklist below and write a list of what materials are available in school and what you need to get yourself and bring into the next class.

Material	Available in school	Must bring in

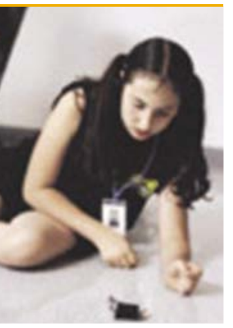
Tip: When planning your model, it is better to plan to build a bigger model so that the details can be seen, tested, and understood.

Session 11

Making it! Models, Trials and Tests

In This Session:

A Making Models (3 x 40 mins)
- Student Worksheet + H/W



Students' design projects move to the tangible and testable. This session provides time to build and test models of components, systems, or the product itself. In the single activity for the session, *11A: Making Models*, students are encouraged to be methodical as they build and report on their models, tests, and results in their design notebooks. This is a session where mentors can support students' work and help them take time to reflect on results and be thoughtful about appropriate next steps.

Supplies

A variety of materials to build models.

Supplies for Structure

- Foam (Styrofoam* in sheets and several shapes, including foam tubes for pipe insulation)
- Foam core board
- Balsa wood (sheets and pre-cut strips from craft supply stores)
- Modeling clay
- Aluminum foil
- Pipe cleaners and plastic straws
- Cardboard (tubes, boxes of all sizes, flat pieces)
- Paper (including poster board or card stock weights)
- Dowels, bamboo skewers
- Wheels

Other Optional Structural supplies

- Recyclable materials such as wine corks, aluminum soda cans, bubble wrap, packaging peanuts, and twist ties
- Sample items (for students to acquire and use in larger constructions): PVC pipe and connectors, lumber (plywood and 2x4s) of different sizes

Session 11: Making it! Models, Trials and Tests (continued)

Parts and Materials To Connect Things

- String
- Wire
- Rubber bands
- Rubber tubing
- Tape (duct, masking, packaging, and electrical)
- Glues (epoxy, superglue, glue sticks, glues for hot glue gun, and rubber cement)
- Hinges
- Nuts and bolts, washers, assorted screws
- Nails, thumbtacks

Tools

- Several sets of each: pliers, saw, hammer, screwdriver, hot glue gun, and tin snips

Session 11, Activity A

Making Models

In This Session:

A Making Models (3 x 40 mins)
- Student Worksheet + H/W

Goal
Learn how models contribute to design.

Outcome
Build models, evaluate results, and consider design modifications.

Description
Students work on their models of the project or trials of components, systems, or subsystems. They are encouraged to be methodical by keeping records of what they plan to construct and why, and what the results show for next steps or modifications to their design.

Supplies
A variety of materials to build models.
(See list on page 209)

Preparation
- Make sure you have a good supply of materials.

Procedures

1. Have students review the worksheet.
2. Discuss the value of good records as they build and learn about their design. Point out that they need to take the time to be methodical and write down what they plan to do and why. As they build and think about what the modeling process shows them, they should keep records about what the design issues come up as they build models. When they complete a model, they "test" it, gather data about results, and write notes about modifications and next steps which may be another model, depending on time available.
3. Clean up and organize storage or transport of models home for further work.

Wrap Up
Have all model makers show what they built and state one or two things that they learned in the process.

Follow With
Session 12 *Prototype Practicalities* allows students to develop the next stages of the project.

intel Education

Making Models

Worksheet: Session 11, Activity A

It is helpful to keep good records of your model building efforts. Good records allow you to adjust your design based on what you learn from each model you build. For each model record your plans, purpose, tests and results, and next steps using the questions below. You may find it easier to use your design notebook for these records.

Design Process Step 8. Build Models and Component Parts.

Plans

What do you want to build a model of? Is this a system or component of the product?

____

____

____

____

Purpose

What will this model help you understand about your design?

____

____

____

Tests and Results

What did your model show you about your design? What functions did you test? Did it function as intended? Did it meet requirements? Did the form suit you? Are the materials suitable? What modifications do you need to make? What new ideas do you have for your design?

____

____

____

11A: Making Models (continued)

Next Steps

What do you want to do next? Adjust this model? Build another version of this model? Build a model of something else?

For the next two class periods and at home you will continue to build your model/s. Remember to use your design notebook to record any changes.

Notes:

Prototyping and Final Presentations

Session 12

Prototype Practicalities

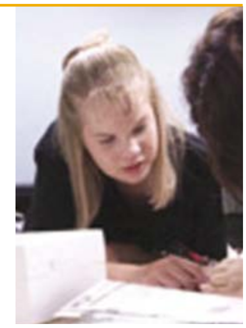
In This Session:

A **Prototype Planning (40 mins)**
- Student Worksheet
- Student Reading + H/W

B **Budget Schedule (H/W)**
- Student Worksheet

C **Prototype Work Session. *Develop it!* (2 x 40 mins)**
- Student Worksheet + H/W

In this session students begin planning how they will construct their prototypes. In *12A: Prototype Planning*, prototypes are reintroduced as students strategize plans and create their specifications for developing a prototype. They also consider what materials they will use to develop their prototypes. In *12B: Budget*, they can use a spreadsheet program to develop budgets for the project.



Student designers' ideas take on new forms as they develop their prototypes. These prototypes should be working prototypes with full functionality. Of course, students may find that as they refine and test their ideas they develop several working prototypes. Activity, *12C: Prototype Work Session* is devoted to prototype development.

Supplies

- Materials to demonstrate what may be used in prototypes:
  - Wood
  - Foam
  - Plexiglass
  - Fiberglass
  - Metal
  - Canvas fabric
  - Bubble packing
  - Cotton balls
  - Tubing
  - Sandpaper
  - Sponges
  - Steel wool pads
  - String or twine
  - Glue
  - Masking tape
  - Duct tape

Session 12: Prototype Practicalities (continued)

Tools
Several sets of each: pliers, saw, hammer, screwdriver, hot glue gun, and tin snips

Supplies

- Spreadsheet software program
- Computers
- Materials to demonstrate what may be used in prototypes:
  - Wood
  - Plexiglass
  - Metal
  - Bubble packing
  - Tubing
  - Sponges
  - String or twine
  - Masking tape
  - Foam
  - Fiberglass
  - Canvas fabric
  - Cotton balls
  - Sandpaper
  - Steel wool pads
  - Glue
  - Duct tape

Session 12, Activity A

Prototype Planning

In This Session:

A Prototype Planning (40 mins)
- Student Worksheet
- Student Reading + H/W

B Budget Schedule (H/W)
- Student Worksheet

C Prototype Work Session. *Develop it!* (2 x 40 mins)
- Student Worksheet + H/W

Goal

Understand what a prototype is.

Outcome

Students will be ready to begin building their prototypes.

Description

This is the first part of Step 9 of the design process: Build the Prototype - develop project specifications. Revisit the difference between a model and a prototype. Students begin to think about how they are going to develop prototypes and get ideas from one another.

Supplies

None

Preparation

None

Procedures

What Is a Prototype?

1. Have students refer back to the design process checklist in *Worksheet: Checking in on the Design Process*, Step 9: Build the Prototype.

2. Ask students the difference between a model and a prototype (this was introduced in *Thinking Again About Design*).

   Model: A small but exact copy of something.
   Prototype: A working model of a machine or other object used to test it before producing the final version.

3. Discuss the purpose of prototypes (learning, communication, integration, and milestones):
   - Learning: Prototypes are often used to answer two types of questions: "Will it work?" and "How well does it meet the users' needs?"
   - Communication: Prototypes allow better communication of product ideas. They are a visual, tactile, three-dimensional representations of a product.

12A: Prototype Planning (continued)

- Integration: Prototypes are used to ensure that components and subsystems of the product work together as expected.
- Milestones: Prototypes are used to demonstrate that the product has achieved a desired level of functionality—providing tangible goals and demonstrating progress.

4. Remind students that as they plan their prototypes, they will have lots of sketches of their ideas before developing the prototype and may develop a few prototypes.

Wrap Up
Be sure that students have a clear idea of the difference between making a model and building a prototype.

Follow With
In: *Prototype Materials*, students consider materials for their projects. The next activity *12B: Budget* gets students planning their materials budget.

Prototype Planning

Worksheet: Session 12, Activity A

Now that you have a model made, it's time to move on to the next step: building a prototype. Remember the differences between a prototype and a model.

Model: A small but exact copy of something.
Prototype: A working model of a machine or other object used to test it before producing the final version.

This is the first part of Step 9 of the design process: Build the Prototype - develop project specifications.

Design Process Step 9. Build the Prototype.

Building a prototype can be fun and challenging. Here are a few tips to keep in mind.

1. Make it large enough. Remember that others will want to see the detail and you will want to make sure all the parts work.
2. Pay attention to detail. Be sure that you show all the parts and components.
3. Make it strong. Use durable materials.
4. Make it "green." Use recyclable materials when possible.
5. Make it realistic. The prototype should be as close to the real product as possible.

Ask yourself the following questions.

1. What ideas do you have for developing your prototype?

____

____

____

2. What suggestions do your peers have for you?

____

____

____

12A Worksheet: Prototype Planning (continued)

3. What materials are you considering using for your prototype?

Fill out the checklist below and write a list of what materials are available in school and what you need to get yourself and bring into the next class.

Material	Available in school	Must bring in

Draw a sketch of your prototype in your design notebook and label the materials.

Session 12, Activity B (Homework)

Budget

In This Session:

- A Prototype Planning (40 mins)
  - Student Worksheet
  - Student Reading + H/W
- **B Budget Schedule (H/W)**
  - Student Worksheet
- C Prototype Work Session. *Develop it!* (2 x 40 mins)
  - Student Worksheet + H/W

Goal
Consider the budget for developing a prototype.

Outcome
Students will create a budget for their materials using a spreadsheet.

Description
In this activity students begin to develop a budget for their materials using a spreadsheet.

Supplies
Spreadsheet software program, computers

Preparation

1. Be sure that if you are going to have students develop budgets on a spreadsheet program, that you have enough computers with the appropriate software for students to do so.

2. You may want to set up a basic template that will help novice spreadsheet users get started.

3. Decide what students' budgets will be (if you are providing the resources).

Procedures
Make a Budget

1. Get students started on a spreadsheet to prepare a materials budget for their project. Use an electronic spreadsheet program to do this. If students are not familiar with spreadsheets, this may take some time to explain how to set up a spreadsheet.

2. Include the following in the budget: material, quantity, and price. Students should list the materials that they selected in the previous activity, figure out how much they will need of each material, and the price for that quantity.

3. Depending on who is doing the shopping for the material (the facilitator or the student), students either give their budgets and materials lists to the facilitator or take them home to serve as a shopping list.

12B Budget (continued)

Wrap Up
Review students' budgets to be sure they are realistic.

Also refer to the Design and Discovery Planner to check out the time available to complete the project.

Follow With
In *Develop It!* Students work on their prototypes.

Budget

Worksheet: Session 12, Activity B

Prepare a budget for your project. Include the materials, how much you will need of each material, the cost for each material, and the total cost.

Materials	Quantity	Cost
	Total Cost =	

Session 12, Activity C

Prototype Work Session. *Develop it!*

In This Session:

A **Prototype Planning (40 mins)**
- Student Worksheet
- Student Reading + H/W

B **Budget Schedule (H/W)**
- Student Worksheet

C **Prototype Work Session. *Develop it!* (2 x 40 mins)**
- Student Worksheet + H/W

Goal
Learn how to develop a working prototype.

Outcome
Build a working, fully functional prototype.

Description
Students work on their prototypes of the project. Be sure to have them keep records to document their progress. Encourage a culture of experimentation. The goal is not to get the prototype done, but to try out different ways that the product could work and find the best solution.

Supplies
See list on page 214.

Preparation
None.

intel Education

12C: Prototype Work Session (continued)

Procedure
Debrief Home Work

Work Session

1. Discuss the purpose of a prototype. Refer back to the purposes from *Prototype Planning:* learning, communication, integration, and milestones. Be sure to emphasize that prototypes are still part of the experimental stage.

2. Remind students that they are wearing two hats: that of an engineer and that of a designer. As an engineer, they should be sure that the prototype demonstrates that the product is feasible, possible, manufacturable, and cost-effective. As a designer, they should keep in mind the idea of user-centered design and continue to ask: Is it useful, usable, and desirable?

3. Have them take out their design specifications from *Worksheet: Prototype Planning* so that they can use the specs when developing their prototypes.

4. Reiterate the value of good records as they develop their prototypes. Remind them that they need to take the time to be methodical and write down what they plan to do and why.

5. Discuss the value of testing and data gathering. Give examples of kinds of testing and how to be systematic. For example, stress load testing on straps. This can be done by adding successive weights to measure up to specifications. Determine how much weight the strap can hold.

6. Clean up and organize storage or transport of prototypes home for further work.

Wrap Up
Have each junior engineer stand up and show what he or she developed so far and state what he or she is planning to do next.

Follow With
In the next session students continue with develop it!

Prototype Work Session

Worksheet: Session 12, Activity C

It is helpful to keep good records of your prototyping efforts. Good records allow you to adjust your design based on what you learn from each step of the process. The questions below can help with this record keeping.

Plans
How do you plan to build your prototype?

____

____

____

Purpose
What will this prototype be able to do?

____

____

____

Testing
Will the prototype meet your specifications? How will you test this and what data will you gather?

____

____

____

Next Steps
What do you want to do next? Adjust this prototype? Build another version of this prototype?

____

____

____

Session 13

Prototype Review and Presentation

In This Session:

A Prototype Work Session. Develop It! (60 mins)

B Test It (20 mins)
- Student Worksheet

C Evaluate and Revise It (H/W)
- Student Worksheet
- Student Reading

D Present It (20 mins)
- Student Handout
- Student Reading + H/W

E Project Reflection (H/W)
- Student Handout
- Student Reading

In this session students take approximately one hour to continue working on their prototype, which they began in Session 12. Being an engineer requires trial and error! Students learn this as they continue with the design process: Step 9 Build the Prototype and Step 10 Improve Your Solution: Test, Evaluate, and Revise. As they develop working prototypes, students test and evaluate the prototypes for function, feasibility, safety and aesthetics and make modifications. This process of testing and modification continues until they have a final working prototype.

In the Activity 13B: *Test It*, students get feedback on function, appeal and value of the product.

In the homework activity, 13C: *Evaluate and Revise It*, they consider the feedback from user testing and prioritise the revisions.

Activity 13D: *Present It*, helps students prepare for an exhibition. It gives them hints on display and presentation.

Finally, Activity 13E: *Project Reflection* gives students the opportunity to reflect on their own progress and their experience in *Design and Discovery*.

Before beginning the session, teachers should read through the session and decide what type of exhibition they wish to have the students do: the Young Scientist and Technology Exhibition (www.btyoungscientist.ie) or an Engineering Fair in their school (which could be part of the Transition Year end-of-year showcase event).

13: Prototype Review and Presentation (continued)

Supplies

For Prototype Construction
As in Session 12

For Presentation

- Flip chart and markers
- Video camera
- Tripod
- Supplies for hands-on activities (if needed)
- Copies of Passport Scavenger Hunt (if needed)
- Copies of feedback forms
- Room decorations
- Food
- Prizes for scavenger hunt
- Science/engineering fair forms
- 3-panel display boards
- Scissors
- Coloured paper
- Rubber cement
- Markers
- Scrapbooking supplies
- Glue sticks
- Other art materials

Session 13, Activity B

Test It!

In This Session:

A Prototype Work Session. Develop It! (60 mins)

B Test It (20 mins)
- Student Worksheet

C Evaluate and Revise It (H/W)
- Student Worksheet
- Student Reading

D Present It (20 mins)
- Student Handout
- Student Reading + H/W

E Project Reflection (H/W)
- Student Handout
- Student Reading

Goal
To get user feedback on function, appeal, and value of the product.

Outcome
To know if the product does what it is supposed to do.

Description
Developing a product does not happen in a vacuum. It is important to remember that the goal is to develop something that others will use. In this activity, students conduct user testing to determine their next steps.

Supplies
None

Preparation
Invite a variety of people to participate in user testing. Ideally, you will ask students to characterize a typical user of their product (as they did in The User) and invite people who represent these users.

Procedures
User Testing Techniques

1. Explain to students that they will conduct user testing to see how their product is received by others.

2. Remind them that when they talk to users, they will need to step away from their personal involvement and understanding of the product and focus on the user. They should listen carefully to what people say, jot down notes, and then decide which comments seem helpful and valid, and which do not.

3. Testing more than one prototype is preferable because the comparison helps people see what they like and what they don't.

4. Explain that the best feedback comes when the designer is as invisible as possible. They can give the user the minimum information necessary and then let the user try the prototypes. The designer should step back and observe.

13B: Test It (continued)

5. If students are participating in the Young Scientist and Technology Exhibition, be sure that they understand the user testing rules.

6. Conduct user testing.

Wrap Up
Discuss how students will use the feedback from the user testing.

Follow With
In *13C: Evaluate and Revise It*, students analyze the feedback from their user testing and plan their next steps.

Test It

Worksheet: Session 13, Activity B

The time has now come for you to test and evaluate your prototype for function, feasibility, safety, and aesthetics and then make modifications. This process of testing and modification continues until you have a final working prototype.

Design Process Step 10. Improve Your Solution. Test, Evaluate and Revise.

User testing will help you to know if your product does what you want it to do. For example, does it work the way it is supposed to? Do people like the way it looks? It's best to conduct user testing with people who you think will be using this product and have more than one prototype (if possible) for them to compare. In order to make the user testing most useful, select appropriate people to do the user testing and appropriate conditions to conduct the testing.

Sample Questions

1. What do you like and dislike about this product?

   ____

2. What do you think this product should do?

   ____

3. What could be done to make you want to use this product more?

   ____

4. What do you think of the way this product looks (the aesthetics)?

   ____

5. Is this product efficient, safe, and comfortable to use? If not, how could it be improved to make it more ergonomic?

   ____

6. What do you see as some problems with this product?

   ____

7. What can be done to solve these problems?

   ____

13B: Test It! (continued)

Additional Questions

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Observations

1. What does the user do with the product?
____

2. What are the user's perceptions of the product?
____

3. How successful or unsuccessful does the user think the product is?
____

4. How does it meet or fail to meet the user's needs?
____

5. How safe is the product?
____

Additional Observations

1. ______________________________

2. ______________________________

Session 13, Activity C

Evaluate and Revise It

In This Session:

A Prototype Work Session. Develop It! (60 mins)

B Test It (20 mins)
- Student Worksheet

C **Evaluate and Revise It (H/W)**
- Student Worksheet
- Student Reading

D Present It (20 mins)
- Student Handout
- Student Reading + H/W

E Project Reflection (H/W)
- Student Handout
- Student Reading

Goal
Evaluate feedback from user testing to plan changes to the prototype.

Outcome
Students will have conceptualized and prioritized changes to their prototype.

Description
Students plan their modifications based on valuable feedback from the user testing.

Supplies
None

Preparation
None

Procedures

1. Students should use the chart to categorize and prioritize the feedback they received from their user testing.

2. Next, have them plan which revisions they will make and how they will make these changes.

3. Students can get feedback from their peers and/or mentors in planning their next prototype.

4. They should consider additional materials they will need and make any necessary changes to their budgets.

5. Check in with each student to ensure they are on track.

6. Remind them to continue work on their prototypes at home.

intel Education

13C: Evaluate and Revise It (continued)

Wrap Up
Review the charts and discuss what changes are realistic.

Follow With
Session 13D, *Present It*, helps students and facilitators make presentation decisions.

Evaluate and Revise It

Worksheet: Session 13, Activity C

Now that you have feedback from your user testing, you need to organize the information in order to figure out which suggestions you will incorporate into your revisions. After completing the chart, decide which revisions are most feasible and what your process will be.

Priority—Decide how this problem ranks.

H = High Priority
M = Medium Priority
L = Low Priority

Problem—Describe the problem.

Criteria—Decide what type of change it is:

- Functional
- Safety
- Aesthetics
- Feasibility
- Other

Revision—Describe what changes would be needed.

Priority	Problem	Criteria	Revision

Session 13, Activity D

Present It

In This Session:

A Prototype Work Session. Develop It! (60 mins)

B Test It (20 mins)
▶ Student Worksheet

C Evaluate and Revise It (H/W)
▶ Student Worksheet
▶ Student Reading

D Present It (20 mins)
▶ Student Handout
▶ Student Reading + H/W

E Project Reflection (H/W)
▶ Student Handout
▶ Student Reading

Goal
Develop presentation criteria, plan presentations and design presentation boards.

Outcome
Students plan their own presentations and summarise their projects on presentation boards.

Description
The students critique the project content and their presentation skills and develop criteria for their final presentations. They then plan their own presentations.

Supplies
- 3-panel display boards
- Scissors
- Coloured paper
- Rubber cement
- Markers
- Scrapbooking supplies
- Glue sticks
- Other art materials

Preparation
In advance, tell students to bring things they may want to put on their boards.

Procedures
1. Study Worksheet 13, Activity D: *Present It*

2. With the group, develop criteria to help students prepare for their presentations.

Wrap Up
Time permitting, students may practice their presentations with one another. Encourage students to practice their presentations at home.

Follow With
The next activity, *13E* students can reflect on their design and discovery experience as a homework activity.

intel Education

Present It

Worksheet: Session 13, Activity D

Design Your Display

You are now ready to design your display for Transition Year night or maybe you are planning to participate in the Young Scientist and Technology Exhibition. It is important when designing your presentation board, to keep in mind several design principles. Attention to the principles of graphic design will make your presentation more enticing and easier for others to use. Good design should attract viewers' attention to your project and then guide their understanding of the information you wish to convey.

Consistency

- Establish a style for your display and stick to it. Too much variation will make your display seem disjointed. Be consistent with all the elements.

Clarity

- Keep questioning whether your message is being conveyed clearly. Do the illustrations and charts convey what they are supposed to?
- Think about the clarity of your visual presentation. Is it cluttered? Question any possibly unnecessary elements like cute stickers, doodles, patterns, etc.

Attention To Detail

- Judges will notice if a display has grammar and spelling errors. Get people to proof your work.
- Make a checklist of the points you want to cover in your display and double-check that you present each.
- Make sure all your pieces are cut out with straight lines (use a ruler) as this will make your presentation look more polished and professional.

Elements Of Your Design

Colour

- Limit your design to two or three colours. Use tints and shades of these. A large number of colours make designs seem less planned and inconsistent.
- Determine how colour will be used and why. For example, you might want all your headers to be one-colour and text blocks to be another, so the headers will stand out.
- Keep in mind that different colours have different connotations and a power of their own. For instance, red usually demands attention. It can be used effectively for this purpose, but only if used in moderation.

Type

- Pick only one or two fonts for the text so your display will look consistent and unified. A large number of fonts, like too many colours, can seem disjointed and confusing.
- Decide on one or two techniques for emphasis in your type style. Some possibilities are: bold, italic, all caps (capitalising all the letters of a word), colour and choice of font.
- Don't use underlining if you have italic available. Underlining was designed to represent italic for typing since typewriters don't have italic.

13D Worksheet: Present It (continued)

- Avoid writing words vertically (with the letters stacked) as this will reduce readability.
- All caps are less readable than standard text, so if you choose to use them, do so only with small quantities of text, such as titles.
- Narrow columns of text are easier to read than wide columns of text. Left-justified or full-justified text is easier to read than centred text (for longer items).

The Presentation
Now that you have completed your project you need to spend some time improving your presentation skills. Conduct a brainstorm with your team members. Ask yourself the following questions:

- What will you need to explain in the presentation?
- What will you need to show in the presentation?
- What presentation skills will make your presentation successful?
- How long is the presentation expected to be?

The following points should help you.

Presentation Content

- Problem clearly described
- Solution clearly explained
- Design process articulated
- Drawings, models, and prototypes explained
- Documentation on hand for questions

Drawing, Models, and Prototypes

- Design drawn in detail
- Models show how project works. Model may include parts and components
- Prototype is a working prototype
- Drawings, models, and prototypes explained in detail

Presentation Skills

- Presenter speaks clearly and explains project in detail
- Presenter is knowledgeable about all aspects of project and can answer questions.
- Presenter is well prepared
- Speaker holds interest (maintains eye contact, uses gestures, varies voice inflection)

Time permitting; you should practise your presentation with other students. You should also practise your presentation at home.

Session 13, Activity E (Homework)

Project Reflection

Goal

To reflect on the fair, students' *Design and Discovery* experience, and to plan for next steps.

Description

Time should be set aside after the fair to reflect on the fair and students' *Design and Discovery* experience in general. Students who are planning to attend another science/engineering fair can begin to plan their project and presentation board revisions.

Procedures

1. After the fair, students should review the Project Feedback forms.
2. Ask students to take some time to answer the reflection questions individually.
3. Be sure to check in with students who are planning to participate in another science fair. Discuss their revision plans.
4. Thank students for their hard work and participation in *Design and Discovery.* Encourage them to pursue their interests in science and engineering.

intel Education

Project Reflection

Worksheet: Session 13, Activity E (Homework)

Project Reflection

1. In general, how do you feel about the fair? What did you like or dislike about it? How would you change it if you were to hold the fair again?

2. How did Design and Discovery meet or not meet your expectations?

3. Would you recommend Design and Discovery to a friend? Why or why not?

4. How did Design and Discovery influence the career you are considering?

5. How do you feel about your project?

6. What changes are you planning to make on your project or presentation board?

Electronics

Electronics

Teacher Notes for Sessions 4 & 5

Introduction

These notes provide background information about the practical work in the students' work book. If you are new to working with electricity/electronics you may find the work a little daunting; but fortunately it is possible to do all of the activities without having to know very much of the theory. Indeed, the students' work book avoids technical explanations of the various 'chips' that are used. This is for several reasons: first, students don't need to know what is happening inside to discover what the chips do; secondly, what is happening inside the chips is far too complicated to explain at school level. However, it is very likely that you, and some students, will want to know more than is written in the work book. The notes that are provided below are designed to give a basic explanation of how the circuits work without getting too technical and worrying about such things as the structure of semiconductors.

Please remember that D&D is a practical course that gives students theory on a 'need to know' basis, rather than treating knowledge/understanding of theory as an end in itself. Thus the 'theory' in these notes is not to be taught as part of the D&D lessons.

Also, experience shows that D&D works best when students work in groups, rather than as individuals. Do encourage them to share their ideas; e.g. in the brief revision of electricity, it is sensible for students to answer thequestions in their groups rather than on their own.

We begin with suggestions about timing of the various activities, followed by a review of basic electricity. Answers to the questions posed in the Student Booklet are given in italics after each question.

Suggested timing of activities

It is in the nature of practical work with groups that some will complete tasks more quickly than others. For this reason not all students are expected to complete all activities. Also, the speed with which students complete the work will vary with their intellectual ability, and with the level of their manipulative skills. However, it is suggested that:

By the end of two D&D sessions, everyone should have completed the introductory work on electricity and activities 1 through 5.

It is likely that many students will comfortably complete these activities. It is then up to you to set them working on one (or both) of the two activities that remain. (Of course, if you have others in mind, feel free to use them instead.)

Electronics (continued)

Basic electricity

The key ideas that students should have met at Junior Certificate Science are those of current (I), voltage (V) and resistance (R). It is enough for them to know that voltage is a measure of the 'push' that a battery, power pack etc. has to move an electric current through a circuit. They should also have learnt about Ohm's law, which is usually stated in symbols as R=V/I.[1] However, what they aren't usually told that almost all the components in circuits that are of any use don't obey Ohm's law. This is especially true of components that contain semiconductors; e.g. light emitting diodes (LEDs), and 'silicon chips' of all kinds. For this reason there are no Ohm's law calculations (or any others) to be done in this module of work!

Indeed, when trying to explain how the circuits work it is best *not* to think about them in terms of patterns like 'a higher voltage will cause more current to flow' etc. Many of the circuits are best considered to work as switches, which are either 'on' or 'off'. A key idea that you will need is that the 'chips' the students will use are electronic switches that are switched 'on' or 'off' according to the *voltage* that is applied to them. For much of the time you will not need to think in terms of current (and certainly not in terms of resistance as defined in Ohm's law).

A point that sometimes troubles students is that it is possible to measure a voltage without a current flowing. In fact, the ideal voltmeter would have absolutely no current flowing through it. A good analogy here is with a car tyre pressure gauge at a garage. The gauge will only be accurate if there is no air escaping from the tyre. Similarly, if you put your finger over the nozzle of a water hose, you can feel the water pressure acting on your finger even though no water is flowing through the hose.

Another point, mentioned in the first page of the students' work book: for some reason students will persist in trying to describe electric circuits using phrases like 'the voltage goes through here', or 'the power goes in here', or 'the battery is not very powerful'. It is essential that such ideas are not reinforced (you may not be able to stop them entirely, but try to encourage students not to talk in such terms). Voltage does not 'go through' anything—voltage does not 'travel'; it is the current that travels through a circuit. However, we can talk correctly about measuring the voltage *across* a component, or about the voltage *at* a point. Think of an analogy with water pressure in a house: if water is fed from a tank in an attic, the pressure of water at a tap in an upstairs bathroom will be less than the water pressure at a tap in a downstairs kitchen. We could measure the difference in pressure, but it makes no sense to say that the pressure is flowing through the pipes: only the water (current) will flow.

Much the same goes for students' use of 'power'. For physicists, 'power' related to electric circuits has a very restricted meaning. It is one that need not concern us here, except to say that use of the term is best avoided. It almost 100% certain that if students do try to use 'power' to explain what is happening in the circuits then they will be wrong.

Finally, a last word about voltage, and batteries.[2] The 9V battery that we recommend of ruse in this module has one terminal marked + (plus) and another – (minus). If you use a voltmeter to measure the voltage between the terminals of a new battery you should find that it is near to 9V. However, please try to understand that this is a *difference*. Strictly we know nothing from this measurement about the *absolute* voltages of the terminals. For example, one could be at +20V, the other at +11V and the difference would still be 9V. Alternatively, if one were at +4.5V and the other at –4.5V, again the voltmeter would measure 9V. The circuit itself doesn't care about our conventions of assigning voltages; but it makes a big difference to how we explain how it works.

1. Actually, to write Ohm's law like that isn't strictly correct; but that is not too important here.
2. At this point physicists will have to accept that we are not going to develop the important distinction between voltage and potential difference.

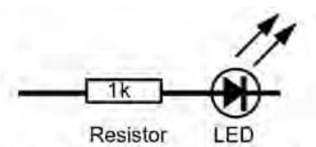
Electronics (continued)

It is best to use this convention: assume that (in spite of the label) the negative terminal of the battery is at 0V, and the positive terminal is at +9V. You will see later that another way of applying this convention it say that a voltage of +9V (or roughly 9V) is given the label 'high' and a voltage of 0V (or nearly 0V) is given the label 'low'.

Light emitting diodes (LEDs)
LEDs are found in very many devices in homes, and elsewhere. For example, almost any remote control for a television or video will have an LED indicator. More elaborate LEDs are being used in traffic lights, where they are arranged in rows/columns of individual lights rather than having one large lamp behind a coloured screen.

An LED has to be put in a circuit the 'right way round'. It has two leads: a cathode that must (eventually) be connected to the negative terminal of a battery, and an anode that must (eventually) connect to the positive terminal. Note: the anode and cathode does not have to connect directly to these terminals.

An LED will switch on only if the voltage across it is (in round numbers) at least 2V. If the voltage is less than that, it will not work. On the other hand, if the voltage goes up much higher, so much current flows through the LED that it will glow very brightly and promptly 'burn out'. For this reason, LEDs are often used in circuits in partnership with resistors. The resistor prevents too much current flowing through the circuit (or put in other terms, it stops the voltage across the LED going up too high).



Standard circuit diagram symbols for an LED with its protecting resistor

If you have looked at some of the diagrams in the students' work book, you will see that where LEDs are used there are no protecting resistors. the reason is that the LEDs that we recommend for use have such a resistor already built into them. Please note: it is most important that you do not use just 'any' LED in place of those that have been recommended for use. "Ordinary' LEDs can be used, but only if protecting resistors are used in series with them. (However, to include the resistors on a bread board makes life much more complicated, and is best avoided.)

CMOS Logic gates
The main 'chip' used in the practical work is labelled as '4093' in the students' work book. In fact the full description of this chip is that it is a 'Schmitt Quad, 2-input NAND CMOS logic chip, code number 4093B'. (Perhaps you can see why the shortened label is used!) Here is a brief explanation of what this chip does. We will take the various terms in the full title in turn, but in a different order.

CMOS
CMOS stands for 'complimentary metal oxide semiconductor'. It is one family of semiconductors that is very widely used in the electronics industry. The details of CMOS need not concern us except for one important point: CMOS chips are very hard to wreck because they can be used with a very wide range of voltages, perhaps as high as 50V. Likewise they are quite tolerant of varying sizes of current flowing through them. However, as all teachers now, nothing is student-proof, and if your students mess with the circuits that have been suggested they will surely find a way to 'blow' the chip. So, it is best to warn them of the consequences of doing other than is suggested in the activities.

Electronics (continued)

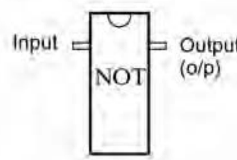
On the other hand, it is always possible that a chip will cease to work through no fault of the students. (There is more about this point below.)

Logic chips and gates

Logic chips are generally found with either 14 or 16 'legs' or 'pins'. Two of these are used to connect the chip to the power supply. Just what the others do varies greatly with the specific chip. Let us consider a simple case of a chip that performs a NOT function: see the diagram and table below.

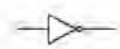
In the diagram opposite is shown a schematic diagram of a 'NOT' logic chip with just one input and one output shown (the connections to the power supply are omitted). If you were to connect the input to the positive terminal of, say, a 9V battery you would find that the output was about 0V. That is, a 'high' at the input gives a 'low' at the output. Similarly if you made the input 0V, the output would be near to 9V; i.e. a 'low' at the input gives a 'high' at the output. This pattern is shown in the table.

A circuit that works in this way is called a 'NOT gate', but typically the chip itself might have seven or eight pairs of inputs and outputs. The symbol for a NOT gate looks like this:

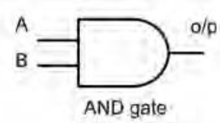


NOT Gate

A	NOT A
0	1
1	0



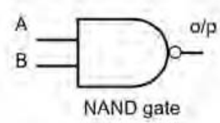
Now let us turn to a more complicated logic gate an AND gate. The pattern here is shown in the table opposite together with the standard symbol for the gate. The key thing about an AND gate is that the output is high only if the two inputs are both high.



AND Gate

A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

This brings us to a NAND gate. Essentially this is an AND gate whose output is put through a NOT gate. The outcome is shown opposite. Note the small circle on the output (as shown on the NOT gate above) indicates that the output has gone through a NOT operation.



NAND Gate

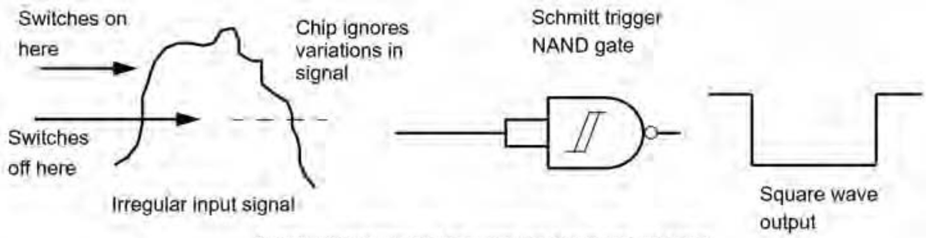
A	B	A AND B	A NAND B
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

Schmitt versions of CMOS chips

It is possible to buy 'ordinary' CMOS chips, but the Schmitt versions have advantages. Specifically, the output is 'cleaned' from any 'noise' in the input signals. The diagram below should give you a sense of what this means.

The two inputs are connected, so that the chip receives only a pattern of two highs or two lows. In practice the inputs can be used separately (as is the case with the students' circuits). Using the Schmitt versions of logic chips can help to make the circuits more stable and perform consistently.

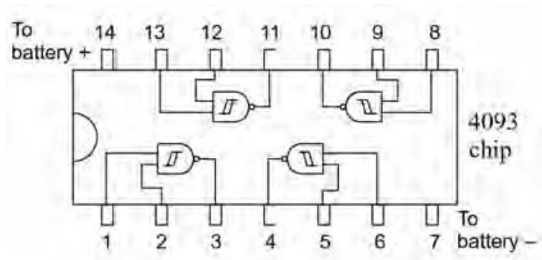
Electronics (continued)



A Schmitt trigger can be used to 'clean up' a signal

Code numbers
There is a wide variety of CMOS logic chips available. Every type has its own unique code number. For example, a 4049UB is a chip with six NOT gates, and a 40106 is its Schmitt equivalent. If you have to order logic chips from a supplier, it is essential to view the catalogue, and make sure that you order the chips using the correct CMOS number. (See later for information about suppliers of components.)

The 4093 circuitry
The 4093 has 14 'legs' or 'pins'. Two of them are used to connect the chip to the battery, the other 12 are used to make four NAND circuits, each with two inputs and one output. The arrangement is shown in the diagram opposite. The student activities only use the NAND gate using pins 1, 2 and 3. However, there is no reason why the other gates should not be used.

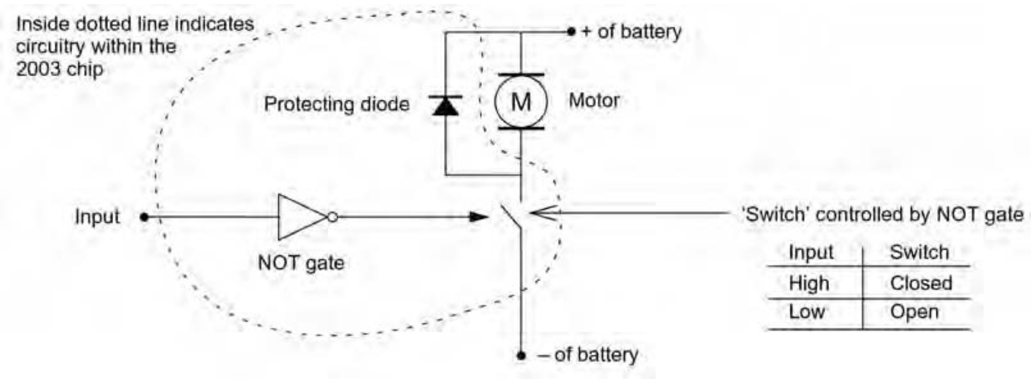


Indeed, if you find that a group's circuit is not working and you can't find any obvious fault with it, then the reason may be that the logic gate has ceased to work properly. It is worth getting the students to try one of the other gates instead. If that doesn't work either, then the entire chip may have 'blown' and should be replaced.

Using motors
Using electric motors with logic chips can cause problems. the reason is that whenever an electric motor switches on or off very high voltage 'spikes' can occur. They may last for only very short times (e.g. 1/10000th of a second), but they can be sufficient to 'blow' the chip to which the motor is attached. This problem can be addressed by using a diode in the circuit. However, even small motors can have relatively large currents flowing through them (say 0.5A), and most logic chips are not able to withstand such currents (well, not for long at any rate). For these reasons, motors should not be connected directly to logic chips.

One solution is to use a chip that goes between the motor and logic chip. Such a chip is the 'ULN2003A Darlington Array', given the code number 2003 in the students' work book. It has protecting diodes built into it, and is able to withstand currents up to 0.5A. This chip also has logic gates built into it so it can 'talk to' other logic chips. A simplified diagram illustrating the operation of the chip is shown below.

Electronics (continued)



The chip is designed so that a 'high' at the input causes a complete circuit to be made to the motor thus causing it turn on. Likewise, a 'low' at the input opens the (electronic) switch, which breaks the circuit and causes the motor to switch off.

Actually the 2003 has seven inputs (and outputs), so it could be used to control up to seven different motors (or other devices); but one would have to be careful not to exceed its maximum current rating.

Resistor colour codes

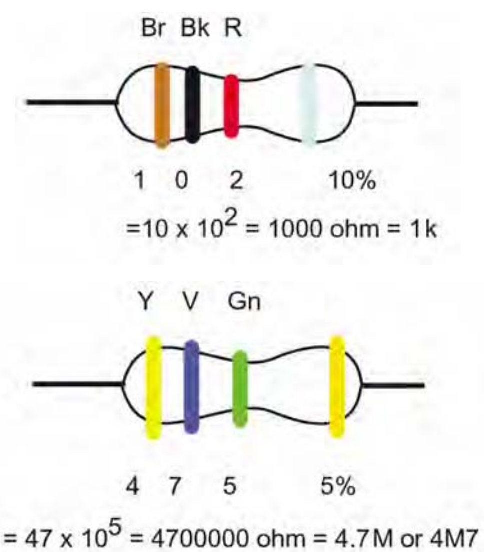
Resistors come in two series—4-band and 5-band. The 4-band are more commonly used in simple work. The 4-band code is as follows:

Bands 1 and 2 give the first two digits of the value; band 3 gives the powers of 10. The 4th band establishes the quality of the resistor—usually 5% or 10% in general purpose resistors. 5% shown by a gold band, and 10% by a silver band. The 4th band is separated from the others, which fact allows us to tell at which end to start counting from.

Resistors come in 'preferred' values; e.g. it is possible to buy a 1k, 1.1k and a 1.2k resistor, but not a 1.05k, or any other value in between the preferred values. You will find out the preferred values by looking in an electronics catalogue. Note that values can be written in two ways e.g. 2.2k or 2k2, 4.7k or 4k7, and so on.

In 5-band resistors, the first three bands are the digits and the fourth band gives the powers of ten.

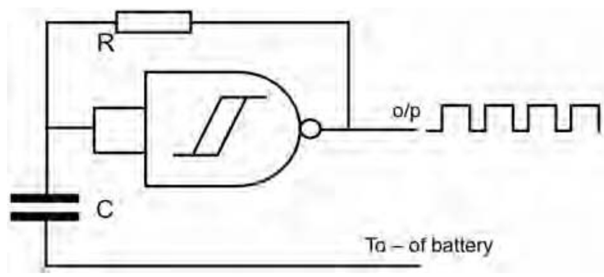
Colour	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9



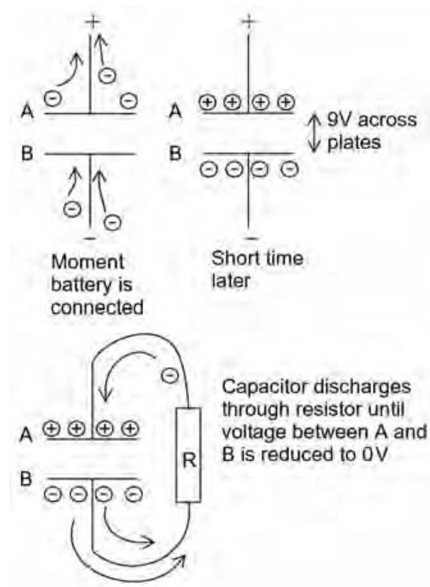
Electronics (continued)

Flashing LEDs

The circuit that some of the students might build to make an LED flash is really a simple pulse generator made from a Schmitt trigger NAND, a resistor and a capacitor. The circuit is shown opposite. The square wave is produced by the repeated charging and discharging of the capacitor through the resistor. Many combinations of resistor and capacitor values may be used.



To understand how the circuit works, you need to know a little about capacitors. Capacitors store charge. You can think of them as having two metal surfaces that are separated by an insulator. (However, the actual construction of capacitors is very different.) On its own, a capacitor will not be charged, so the voltage across its terminals will be zero. However, if you connect the terminals to a battery, one of the surfaces (labelled A on the diagram) connects to the positive terminal and one (labelled B) connects to the negative terminal. Electrons that are free to move on A will be attracted to the positive terminal of the battery, so will travel towards the battery. When they leave A, a positive charge is left behind. This positive charge will attract electrons on B, and from the negative terminal of the battery towards it. Eventually all the electrons that could move off of A will have done so, at which stage the process comes to a halt with a layer of positive charge on A and a layer of negative charge on B. Where there is a separation of charge there is a voltage difference, and you would find that if you were using a 9V battery, the voltage across the terminals of the capacitor would be 9V also.

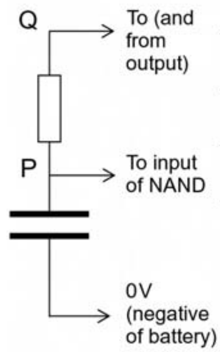


In principle, you could disconnect the capacitor from the circuit, and the extra charge on A and B would remain until you connected a conductor between the two terminals. Then the electrons on B would rush round to A, and the capacitor would have discharged. The charging and discharging of a capacitor can be slowed down by putting a resistor in the circuit—here the resistor lives up to its name by resisting the flow of current.

The ability of a capacitor to store charge is measured by its capacitance, and is measured in 'farads'. A capacitance of one farad, 1F, is in practice a very a large value, and in most work with logic chips etc. values of microfrarads

Electronics (continued)

(μF) and picofarads (pF) are more common (1 μF = 10 –6 F; 1pF = 10 –12 F). The larger the value of the capacitor, and the larger the value of the resistor in series with it, the longer it takes for the capacitor to charge and discharge.



	Start	Next	Then	And then
Voltage at Q	9V	1V	1V	9V
Voltage at P	9V, i.e. 'high'	starts to fall	reaches a 'low'	9 V
Output of NAND	'low', say 1V		goes 'high', say 9V	'low', say 1V

Now, let us return to the circuit that uses the logic gate. Suppose the capacitor has become fully charged. Then the voltage at P will be equal to the battery voltage, 9V. This represents a 'high', so the output of the NAND will be 'low' (say 1V). But as soon as the output goes 'low', the voltage at Q will also be 'low'. The charge on the capacitor will then 'leak' out through the resistor and at the same time the voltage across the capacitor will fall. That is, the voltage at P will start to drop. However, when the voltage goes low enough the NAND gate will recognise that the input has gone from a 'high' to a 'low'. Then the output will immediately change in the reverse direction—to a 'high'. At once the current will flow from the output through the resistor to recharge the capacitor. The voltage at P will gradually rise to 9V again, and the whole cycle repeats.

The time it takes to charge and discharge the capacitor changes if the values of the capacitance and resistance are changed—higher values, longer times (and vice-versa). Students should find that a 1k resistor with a 1000 μF capacitor gives a sensible rate of flashing (1 per second or so), as does a 47k resistor with a 10 μF capacitor. A 1k with 10 μF appears to stay on permanently because the flashing is so fast; the 47k with 1000 μF may give the impression of not flashing because the delay is so long.

Using bread boards

It may be that you have never used bread boards before. If so, you may find the following 'hints and tips' useful. First, if the bread boards are new, it may be difficult for the students to get the wires to go into the holes because the connectors underneath are too stiff. The connectors can be eased by pushing one of the legs of a resistor into the holes that are found to be difficult to use.

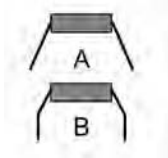
On the other hand, if the same holes are used a great deal, the connectors can become quite loose. If this happens, the wires go in very easily, but may not make good connections. It can be necessary to 'fiddle' with the wires before a good connection is made.

Emphasise to the students that the bread boards should all be aligned in the same way (as shown in the photographs). that is, with the rows of five holes going vertically, and the long lines of holes (where the battery is connected) going horizontally. If they don't all use the same orientation of the bread board it makes it very difficult for them to build the circuits properly, and for you to check them if/when necessary.

Electronics (continued)

The wires connecting the battery to the bread board may become frayed after a few uses. If so, the plastic coating will need to be stripped back to revel more of the wire. If you are used to soldering, it can be useful to apply a little solder to the ends of the wires in order to stiffen them.

When new, the chips that have to be used will not fit directly into the holes in a bread board. the legs are splayed out, as shown in the diagram (A). Before you give the chips to the class, you (or a trusty student) should push the legs inwards, e.g. by pressing them down gently (!) against a table top until they are almost vertical (B).



Also, in order to avoid the students making mistakes about the correct orientation of the chips. It is best to label them (as shown in the photographs). There is almost always a small indentation in one end of the top face of the chip (often a small semicircle) that marks where the numbering of the pins begins. The label should read correctly from left to right with the indentation on the left hand side of the label.

Motors

The motor that we suggest using in this work is fairly robust. It will run off of a 1.5V battery, and draw a current of about 0.5A. It has the advantage of being fixed to a metal platform, which could be screwed down to a larger wooden base. Using it with a 9V battery for short periods does not do it any harm; but it should not be left running for long periods; i.e. a minute or more. Please emphasise this point to the students.

The motor has a speed of nearly 4000 rev/min. (as stated in the students' work book). This is too fast to be used to drive (say) a small buggy. However, the final rotation of the wheels to which it might be attached can be reduced by suitable gearing.

Before the motor is given to students it should have two connecting leads soldered to its terminals. (Advice will be available if you have had no experience of soldering.)

There is more work on motors in the mechanics section of the course.

Coping with components

The number of components that students need to use is not large; but owing to their small size, they are easily lost and/or damaged. It can be useful to give each group of students a set of equipment in a plastic 'lunch box' or food container that has a tight-fitting lid. Also, it can be very handy to have one or more pieces of (flat) polystyrene foam (e.g. as used in packing). The components can be safely pushed into the foam to keep them from getting jumbled up.

Electronics (continued)

The following is list of equipment that should be provided for each group. The data refers to the Maplin 2003/4 catalogue.

Item	Number	Maplin part no.	Page
Breadboard	1	AG10L	165
9V battery (PP3)	1	AR46A	483
clip for battery	1	NE19V	502
4093B CMOS chip	2	QW53H	208
2003A Darlington Driver chip	2	AD93B	208
Small 3V lamps	2	L81AH	534
Lamp holders	2	VW65V	536
Resistors, 1K, 10K, 22k, 47k	2 of each	G1K, G10K, G22K, G47K	177
Capacitors, 10mF, 22mF, 47mF, 100mF	2 of each	VH22Y, VH26D, VH32K, VH37S	81
LEDs, red, green	2 of each	J64U, CJ65V	136
Motor	1	HA83E	644
Reed switch and magnet (sold as pair)	1	YW47B	558
Push switch	1	FH59P	241
Micro switch	1	N96AQ	239
Buzzer	1	FL39N	761
Selection of wires—best purchased as a kit that should supply enough for all groups.	8 (say)	FS65V	166

Suppliers of electronics components
There are many suppliers of electronics parts; but we list just three here:

Maplin Electronics, Unit 1–4 Jervis Street, Dublin 1 and Unit 413, Blanchardstown Retail Park, Dublin 15. Maplin has a very wide range of equipment and a comprehensive catalogue; but it doesn't always carry a complete range of stock. However, it has an efficient mail order system via the web at www.maplin.co.uk.

Peats World of Electronics, 197/200 Parnell Street, Dublin 1.

Radionics, Glenview Industrial Estate, Herberton Road, Rialto, Dublin 12.

Electronics (continued)

Explaining the behaviour of the students' circuits

The first point to realise is that the D&D course is not about students' reaching a good theoretical understanding of the circuits they build. Rather, the emphasis is on them getting practical experience of building circuits, and knowing what the circuits do. They should also be able to link their observations to wider contexts; especially in relation to possible uses of the circuits in their later projects, and in industry or the home. Thus, we think there is no harm in saying that at Transition Year level, the working of the chips is just too complicated to explain. This happens to be true; but it doesn't mean the students can't make the circuits work.

Notes:

Motors

Motors

Teacher Notes for Session 6 Activity C

This activitiy is based upon the use of a LEGO kit. How many of the kits you have available will mainly depend on finance. Ideally there would be one kit per group, but if you have just one it is possible to use it as part of a class activity.

The key aims of this work are to introduce students to the practical uses of motors (e.g. in food mixers, cars and the like) and the use of gears to transfer motion from the motor to the wheels etc. The way this is done is to involve the students in a series of short activities with the LEGO kit. Most of the work is straightforward, but it does require the students to measure, and think! As usual, the idea is that students discuss the tasks, questions etc., with each other in their groups. The notes that follow should be read in conjunction with the student instructions.

Exercise 1

Building the buggy is not too difficult, but there are more parts in the kit than the students need. It would be best to issue the kit with only the parts they need. A convenient way to do this is to put the parts in a good quality sealable freezer bag, or a small plastic lunch box. Note: six AA batteries are needed for each controller box. (The latter can be difficult to open.)

1. There are 24 cogs on the large gear wheel.
2. There are 8 cogs on the small gear wheel.
3. The students might describe this in words and/or with a diagram. Note that the gear wheels in question have identical numbers of cogs.
4. Stable can have several meanings; but the key things are for the students to think about relevant factors. Key ones are: the motor is heavy and is (roughly) in the middle so the weight is fairly evenly distributed; however the motor is quite high, so the centre of gravity will fall outside the base if the buggy tips too much. When you go over their answers it would be useful to stress such factors in the design of cars (for general use and, say, in Formula 1 racing). Needless to say, students will have fun trying out the buggy. How much you can stand of this will depend on you!

Exercise 2

1. Students may suggest many different ways, some of which will not be possible in a lab or class room. However, do let them try out different ways if at all possible. One way that we have tried is to measure out 1m, and time the buggy over that distance. It is necessary to have a timing device that measure to at least 1/10th of a second—many mobile phones have such a facility. Doing that, we observed a time of (about) 1.2seconds, which gives a speed of 100cm/1.2 s = 88.33 cm/s. The accuracy is not that good of course: the main errors are getting accurate times when there is variation in starting and stopping the stop-watch/timer. Probably the inaccuracy is of the order of 30% (possibly more) when short times are being measured. A mechanical device for controlling a time would be best. This could be a possible use of a microswitch attached to the buggy (see the electronics module); but a datalogger would be best.

Motors (continued)

Another point to be aware of is that it take time for the buggy to get to its top speed, so ideally it is best to time it not from a standing start, but when it crosses a mark already moving.

2. One key idea is to repeat measurements, so as to obtain a better estimate. If you are confident with its use, this could be an ideal opportunity to use datalogging equipment to measure the speed of the buggy.

3. The diameter is about 3cm, so the radius is 1.5cm and the circumference is about 9.42 cm.

4. Using our result, the buggy travels 88.33cm in one second, so the number of revolutions is 88.33/9.42, i.e. 9.34 revolutions per second. The number of revolutions per minute is 60 times greater, i.e. 563 revolutions per minute.

Exercise 3

1. The small gear wheel will go round 24/8 = 3 times for each revolution of the large wheel. That is, the wheels will be rotating three times faster than the motor shaft.
2. If the speed were 300 rev/min, then the motor shaft would turn at 100 rev/min.
3. We found a speed of 563 rev/min, so the estimate for the motor speed is 188 rev/min.
4. The result is almost 50% less than the LEGO figure. Reasons for the difference include: errors of timing (see above), slipping of the wheels on the floor/bench, batteries not being at 9V (so motor turns more slowly than stated by LEGO). Note: a datalogger should give a much better estimate, but only if the timing starts when the buggy is at top speed.

More about gears and using motors

Q.1 Put the large gear on the wheel shaft, and the small on the motor shaft.

Q.2 Easier to move with low gearing; that's why cars start in 1st gear and gradually change up to 4th once the car is moving more rapidly.

Q.3 and 4. The lever is for changing the gears in the mixer. The first setting might be used for mixing dough for bread (thick/heavy and hard to move). The last setting might be used for beating egg whites (light and easy to move)

Follow-up work

The working of a clutch is best explained using diagrams e.g. from auto.howstuffworks.com/clutch.htm. Depending on the nature of the groups, it can be worthwhile asking each group to give a short report to the whole class. The Prius is a car marketed by Toyota (at less than cost price) that uses a combination of electric and petrol motors. The electronics swaps between the two to give the most economical running. The search for a fuel-efficient engine is becoming much more pressing as oil prices rise. Problems remain with making batteries efficient but able to sustain sensible mileages while keeping their weight down. They are not so environmentally friendly as might be thought at first sight—if they are plugged into the mains, then more fuel is used in power stations (more carbon dioxide released etc.).

How students tackle the design issue will vary greatly; but main issues might be the nature of the tasks the mixer is to carry out (distinguish mixers from blenders?); weight and size: the more powerful, the heavier the mixer has to be to remain stable in use; elegance of design (contours, colour etc.).

Post-Survey

Design and Discovery Post-Survey

What you think is important to this science project. Please answer the questions below honestly. There are no right or wrong answers, and your surveys will be kept confidential. Thank you for sharing your thoughts. Circle the number indicating your level of agreement with the statements.

	Disagree	Disagree a little	Agree a little	Agree
1. I understand what I need to do to complete my project display at the TY end of year event and how to enter in the Young Scientist and Technology Exhibition.	1	2	3	4
2. Learning how computers work is interesting.	1	2	3	4
3. Continuous advances in computer technology are important.	1	2	3	4
4 I understand how I can use the computer for my science fair project.	1	2	3	4
5. I would like a career that requires a math or science background.	1	2	3	4
6. I would like a career that involves designing things.	1	2	3	4
7. My future career requires a computer . technology background.	1	2	3	4
8. I am good at solving problems.	1	2	3	4
9. If I try hard, I can learn anything.	1	2	3	4
10. I like to find out things on my own.	1	2	3	4
11.I am informed about different kinds of jobs that use:				
Maths.	1	2	3	4
Engineering design.	1	2	3	4
Science.	1	2	3	4
Computer technology.	1	2	3	4

12. Describe what you think an engineer does at work. What kinds of skills are needed to become an engineer?

Design and Discovery Post-Survey (continued)

	Disagree	Disagree a little	Agree a little	Agree	X
In Design and Discovery it was interesting to:					
Interview and talk to engineers	1	2	3	4	X
Talk with teachers	1	2	3	4	X
Learn about problem solving	1	2	3	4	X
Work on group projects	1	2	3	4	X
Work on my science fair project	1	2	3	4	X
Use the computer for research	1	2	3	4	X
Use the computer to talk to other students	1	2	3	4	X
Talk about my work	1	2	3	4	X
Learn about design	1	2	3	4	X
Draw designs	1	2	3	4	X
Take field trips	1	2	3	4	X

Did you go on any field trips? ____________ Where? ______________________________

Why? ______________________________

____

I plan to enter the science fair this year. ☐ Yes ☐ No ☐ Not sure

Do you know what your project will be? ☐ Yes ☐ Not completely ☐ No

If 'Yes', what is your topic?

____

First two letters of your:

____ ____ first name*

____ ____ last name*

____ / ____ / ____ Date of birth*

Thank you for your time and thoughts.

**This information will allow us to follow your responses over time.*
We will summarize all data, however, and no one will be identified.