Instructional Practices

Implementation Strategies

Design and Discovery is most successful when facilitated as an inquiry-based and student-centered program. This section provides suggestions for facilitating *Design and Discovery*.

Approach
The *Design and Discovery* curriculum follows the principles of project-based learning. This area provides more information about the educational approach taken in *Design and Discovery*.

Strategies
Design and Discovery has been implemented in a variety of settings. This section offers suggestions for facilitating the program based on proven successes.

Logistics
Project work involves details that need to be thought through. This section provides assistance on managing projects and supplies.

Student Materials
Like professional engineers and designers, *Design and Discovery* students use design notebooks to record their ideas, respond to questions, and sketch drawings. This section provides information on using design notebooks, the student handouts, and other student materials.

Safety and Tool Use
Students use a variety of hand tools throughout their project work. This section provides tips on how to use these tools safely.

Approach

Instructional Practices

Applies Principles of Project-Based Learning
Project-based learning is an instructional model that involves students in investigations of compelling problems that culminate in authentic products. In *Design and Discovery*, students identify a design problem that is relevant to their own lives and come up with an innovative solution. Through hands-on work, they create design briefs, sketches, models, and working prototypes of their design solution. The work is inherently meaningful because it allows students to pursue their interests and engages their curiosity. Much of students' work takes place in the real world, outside the classroom, where they conduct surveys, gather data, talk to professionals, observe users, test their products, and showcase their projects.

Engages Students in Inquiry-Based Learning
Design and Discovery is an inquiry-based curriculum that encourages higher-order thinking. 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. Through hands-on activities, they gain an understanding of basic mechanical, electrical, and materials engineering principles that can be applied to their design solutions. As students develop their models and prototypes, they determine-with the help from mentors and experts-what engineering principles they can apply to their own designs.

Uses Tools of Professionals
Design and Discovery follows a 10-step design process used by professional engineers and designers. The design process guides students through their project development, beginning with the identification of everyday problems and culminating with developing and presenting a working prototype. As students follow the design process, they use other tools of working engineers and designers. They learn how to write a design brief, create conceptual drawings, use creative brainstorming techniques, develop models, and make working prototypes. They develop the lifelong skills of working collaboratively, being problem-solvers, and presenting their ideas. Through this process, *Design and Discovery* students assume the roles of real engineers and designers.

Follows a Sequential Order
The *Design and Discovery* curriculum is divided into 18 sequential sessions, each with two to four hands-on activities. The order of the sessions mirrors the design process, and it is therefore strongly recommended that the order not be rearranged. Engineering fundamentals are included after students are introduced to the design process and before they delve into their own projects. This allows students to refer back to their learning from these engineering sessions and decide what engineering principles they may want to incorporate into their

Approach (continued)

designs. By the end of the *Design and Discovery* experience, each student will have his or her own working prototype. Many students may wish to further refine their design solution and enter engineering and science fairs.

Builds Interest in Engineering and Science Careers

Research has shown that in middle school many students lose interest in science and math and end up taking fewer of these classes in high school, which ultimately closes doors to math and science careers. One of the goals of *Design and Discovery* is to generate interest in engineering and science for students who may not otherwise be interested in these areas. Students who experience *Design and Discovery* soon acknowledge that this is not a typical science class. Many students who were not previously interested in engineering careers express interest after the program. Mentors are integral to *Design and Discovery* and help to further students' exposure to engineering and science careers. Field trips can also serve this purpose by providing students first-hand experience with working professionals. *Design and Discovery* culminates with a final presentation of students' projects where students have an opportunity to share their expertise and demonstrate their projects to the community.

Strategies

Instructional Practices

Facilitation

Design and Discovery is a student-centered experience. The facilitator should establish a safe environment where students are encouraged to ask questions, pursue their ideas, conduct tests and trials, and make mistakes. The facilitator should assume the role of consultant throughout the *Design and Discovery* experience and understand that he or she does not need to be the expert with all the answers. The facilitator should encourage students to seek answers to their questions through conducting research, talking to experts, and testing their ideas.

Facilitators may find that some *Design and Discovery* students wish to pursue ideas that may seem very large and probably unrealistic. However, students should never be discouraged. The facilitator can help redirect them or help them to narrow their focus by breaking down an idea into smaller parts. It is important to remember that *Design and Discovery* is about the process of getting from "think" to "thing" and not just about the final product.

Grouping

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

Ideas for Assigning Groups

- Deal playing cards to each student. Form groups by numbers, suits, or colors.
- Divide students based on common characteristics: clothing, hair color or style; alphabetical by first, middle, or last name.
- Have students draw names.
- Roll dice to choose a random number. Assign groups by numbers or evens/odds.

It is also up to the facilitator 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. Students working together should also be in the same grade level, especially if they want to enter an Intel ISEF-affiliated science fair. Check with your local fair for rules on group projects.

Bringing in Experts

Experts may be brought in to support *Design and Discovery* students at any point. Experts are most useful during the engineering fundamentals sessions if the facilitator does not have an engineering background. Experts may be drawn from parents, community members, universities, and local businesses.

Strategies (continued)

Mentors are integral to *Design and Discovery*—especially during the phase of individual project work. See Mentors for more information about recruitment and responsibilities of mentors.

Assessment
While assessment is not built into the *Design and Discovery* curriculum, the curriculum does lend itself well to portfolio assessment. Portfolios allow students to represent the learning that has taken place during the *Design and Discovery* program. This curriculum involves identifying a need that could be met by redesigning, modifying, or improving an existing product or designing a new product. Students can collect and reflect on examples of their work throughout the program and present them as portfolio entries at the end of the program. Portfolio entries could include evidence that explains the design goal and the planning, implementation, results, and evaluation of the design solution.

Electronic portfolios offer an innovative alternative to more traditional portfolios. A digital portfolio might use multimedia technology, allowing students to collect and organize their portfolio components in a variety of mediums, such as video, audio, text, and graphics. For example, taking digital photos to document the design process, recording reflective video, using narration to describe aspects of the design solution, or creating a 3D simulation of a working prototype can all be highlighted through the creation of an electronic portfolio. An electronic portfolio, if published online, offers students a creative way to present their learning to a larger audience while also increasing their technology skills.

The curriculum also provides many embedded assessment opportunities where observational data can be used as an ongoing record of student understanding. Discussion and student handouts supply another avenue for checking understanding of key concepts.

Logistics

Instructional Practices

Managing Projects

As students create models and prototypes, they will need a safe place to keep them. Keep in mind that some of the projects may be rather large. Also, students may be transporting them between home and the *Design and Discovery* site and will need to have a safe way to transport their project. Advise students that they should take this into consideration when developing their models and prototypes. Be sure that they use strong materials and create something to hold their project to make it easier to store and transport.

Work Space

It is recommended that a *Design and Discovery* program be held in a spacious room with tables. Students need space to work on activities and build their models and prototypes. The room should also have a closet to keep supplies and a safe place for students to keep their projects. Students will also be working collaboratively through much of *Design and Discovery* and will need a room layout that is conducive to this. Since *Design and Discovery* is not an online curriculum, it is not recommended that it be held in a computer lab, although access to a computer lab is important for Session 9 and access to a presentation station is helpful in Session 4, 12, and 16 to show student videos.

Managing Supplies

Each *Design and Discovery* session and activity includes a supply list. The entire supply shopping list is also available. All supplies may be purchased up front or may be bought as needed. Many of the supplies can be donated by students, mentors, and other volunteer organizations. Many vendors may also offer a discount for materials purchased in large quantities and for a youth program.

It is suggested that supplies be kept in a safe closet. A day prior to each session, organize the supplies for that session. Non-consumable supplies may be used over and over so be sure that they remain in good condition.

Supply Resources

Building, Electrical and Lighting, Hardware, Plumbing, Tools
The Home Depot
800-430-3376
www.homedepot.com*

Craft Supplies
Michaels

Logistics (continued)

www.michaels.com*

Electronics
Radio Shack
www.radioshack.com*

Office Supplies
Office Depot
888-463-3768
www.officedepot.com*

Science Supply Houses
Carolina Biological Supply Co.
800-334-5551
www.carolina.com*

Pitsco
800-828-5787
www.pitsco.com*

Student Materials

Instructional Practices

Design Notebooks

A student composition book can be used as a design notebook. These notebooks should be used throughout the curriculum for students to record everything related to *Design and Discovery*, from responses to answers on the student handouts to design sketches. Students can write the questions from the handout on the pages of the design notebook. It is recommended that each student have a student composition book with grid lines. The gridlines will help students as they begin sketching their ideas.

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 an Intel ISEF-affiliated science fair 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.

Student Handouts

Each activity includes a student handout. These can be provided for students all at once in a three-ring binder or may be handed out session by session. Students should not write on these, but should do all of their writing and sketching in their design notebooks.

Video Journals

Video journals are optional. 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.

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*.

Student Materials (continued)

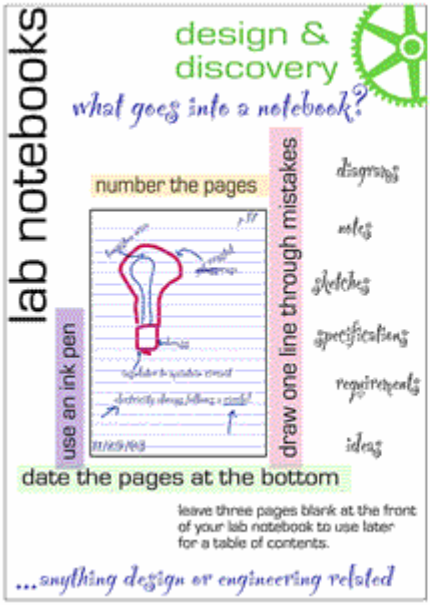
- Explain what your goals are for your project and how you plan to meet them.
- Explain what has been most helpful so far in developing your project.

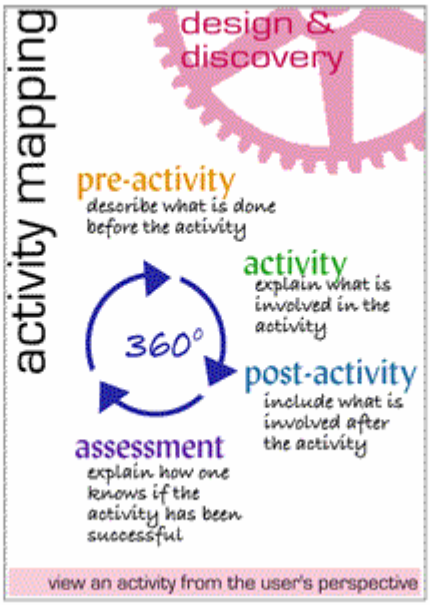
The video can be shared with the students throughout *Design and Discovery* as a way to discuss and reflect upon the design process. It may be shared with parents so that they can see what their child is thinking and doing in *Design and Discovery*. It can be edited and made into a short video piece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

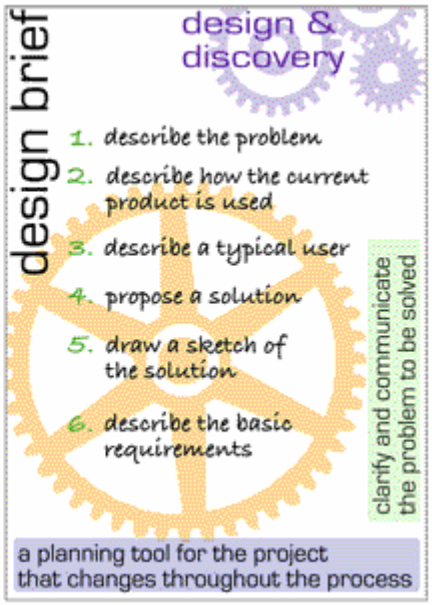
Student Resource Cards

Throughout the *Design and Discovery* curriculum, students are introduced to design and engineering concepts and brainstorming techniques. A set of six Student Resource Cards (PDF; 1 page) is provided as a student resource. All six cards can be printed on one sheet. The cards can then be cut into individual cards and distributed to students during the activities listed below.

- For Session 1, Activity A, use Discover an Engineer and Design Notebook.
- For Session 1, Activity B, use The Design Process.
- For Session 2, Activity B, use Activity Mapping.
- For Session 2, Activity C, use SCAMPER.
- For Session 8, Activity B, use Design Brief.







Safety and Tool Use

Instructional Practices

Tool Safety
Students use a variety of tools throughout *Design and Discovery*. Before using tools, be sure to demonstrate proper use of the tool and point out safety precautions.

General safety rules:

- Keep the work area clear of clutter.
- Maintain and keep tools sharpened, oiled and stored in a safe, dry place.
- Wear eye protection when cutting, sawing, drilling, or grinding.
- Inspect tools regularly.
- Use the right tool for the job, for instance, do not use a screwdriver as a hammer.
- Carry a sharp tool pointed downward.
- Protect a sharp blade with a shield.
- Store tools in drawers or chests with cutting edge down.
- Train all mentors in the proper use of hand and power tools.

Tools
The following tools may be used throughout *Design and Discovery* sessions:

Needle-nose pliers: Needle-nose pliers are used to bend and shape wire. Needle-nose pliers are used in Session 1 when students design their own paper clips and in Session 5 when students make a mechanical toy. Students may also need to use pliers during the modeling and prototyping phase of their projects. Be sure that students carry the pliers pointed downward.

Wire cutter/stripper: Wire cutters and strippers are often combined in one tool, but may also be purchased separately. Wire cutters and strippers may be used in Sessions 1 and 4, depending on what type of wire is used. Some insulated wire is already partially pre-stripped for use, while other wire may need to be stripped. To use a wire stripper, identify the gauge of the wire and place the wire in the proper hole, and then pull the insulation away and off of the wire. Wire cutters are used when the length of the wire needs to be modified. Some wire comes pre-cut. Check the supply list for each activity to determine the length of the wire needed. To use a wire cutter, place the wire in the sharp part of the blade and cut at a right angle. Never rock the wire cutter from side to side or bend the wire back and forth against the cutting edge. Point tools away from you when stripping or cutting wire.

Safety and Tool Use (continued)

Screwdriver: Small Philips* screwdrivers are used in Sessions 4 and 6. In Session 4, they are used to screw the wire to the battery and lamp holders. (Some battery holders may be pre-wired.) This can be done beforehand by the facilitator or during the session by the students. In

Session 6, screwdrivers are used to take apart clock radios. When using a screwdriver with electrical equipment, be sure to use an insulated screwdriver. Place object on a table, not in the palm, when using a screwdriver.

C-clamp: Clamps are versatile tools that serve to temporarily hold work securely in place. C-clamps are used in Session 3 to hold materials in place when conducting a materials properties test. When using a clamp, ensure that the pressure plate is in full contact with the workspace before tightening. Pads can be used with C-clamps to avoid marking the surface.

The following tools may be used when students are working on their models and prototypes.

Hand saw: Saws are made in various shapes and sizes and for many different uses. Be sure to use the correct saw for the job. Choose a saw with a handle opening of at least 5 in. (12 cm) long and 2.5 in. (6 cm) wide and slanted at a 15° angle. Before cutting, check for nails, knots, and other objects that may damage the saw. If material is long, place in a vise. Start the cut by placing your hand beside the cut mark with your thumb upright and pressing against blade. Start the cut carefully and slowly to prevent blade from jumping. Pull upward until blade catches the wood. Start with partial cut, and then set saw at proper angle. Apply pressure on the down stroke only.

Hammer: Hammers are made for specific purposes in various types and sizes, and with striking surfaces of varying hardness. Select a hammer that is the proper size and weight for the job. When striking a hammer, strike squarely over the surface. Be sure to have an unobstructed area to swing a hammer. Use the correct type of hammer for the work. Keep your eye on the object you are hitting. Hold the hammer with your wrist straight and your hand firmly wrapped around the handle.

Hot glue gun: A hot glue gun is ideal for gluing wood, metal, fabric, ceramics, masonry, leather, cardboard, and PVC. Insert glue sticks when glue gun is in off position. Keep fingers away from hot glue.

Knives: Knives may be used to cut thicker materials. Always cut away from the body. Keep hands and body clear of the knife stroke.

Tin snips: Tin snips are useful for cutting sheet metal, plastic, and linoleum. Do not attempt to cut heavier materials than the snips are designed for. Never use tin snips to cut hardened steel wire or other similar objects. Such use will dent or nick the cutting edges of the blades. Be

Safety and Tool Use (continued)

careful of the sharp edges of the materials and tool. Use only hand pressure for cutting. Never hammer or use your foot to get extra pressure on the cutting edges.

Goggles and Gloves
Students should always wear goggles and latex gloves when working with tools, wire, and other sharp materials.

Wire
Wire is measured in gauge which refers to the size of the wire. The higher the gauge number, the thinner the wire. The lower the gauge number, the thicker the wire and the more amps capacity it has to carry current further from the electrical source. *Design and Discovery* students will be using different gauged wire for different uses. In session one, they use steel or copper wire, 14 or 18 gauge to make paper clips. In session four, electrical engineering, they use 22-gauge wire that is stripped 0.25” and bent 90 degrees. Use a wire stripper to strip insulation from wire and a wire cutter if wire needs to be shortened.