Team Problem Solving Contest – Middle and High School

2007 Project SkillsUSA –Professional Development

In order to accommodate the number of students participating in this contest, the problem solving competition is divided into three sections. Each section challenges students to apply their problem solving skills in the context of a technological theme. The three themes used to facilitate the contest are **product design**, **structures**, and **mechanisms**. The product design contest develops a mock-up for a product that fulfills a given function. The structures contest asks students to design and build a simple structure that will carry and distribute a given load. The mechanisms contest engages student in developing and testing a mechanism that will perform a given task through the motion of simple and compound machines.

The Contest

Students participate in teams of 3 to 4 students. Each section is divided into three parts. The first part requires students to demonstrate their knowledge of problem solving and design on a written objective test. In addition to questions on design and problem solving, the test will also include items that address the theme in question (i.e., structures, mechanisms, product design). The second part will ask students to design and build a model that reflects their best solution to a given problem. Lastly, students will be required to test or present their solution to the problem.

Each segment of the contest will evaluated. One third of the total score will be the performance on the test. Another third of the score will come from the work they do on in a design portfolio that describes their thought processes (e.g., thumbnail sketch, anecdotal notes, final sketch, reflections). The final third of the score will be based on the extent to which their model addressed the problem they were asked to solve.

The Written Objective Test

After a short orientation, students will be asked to put their group number on the upper right hand corner of an envelope. Students will then be asked to retrieve a test and an answer sheet for each member of their team. Every member of the team will take the test and they will need to record their answer on the answer sheet. Given the fact that it is a team competition, students will be allowed to discuss the items and record their answers as they see fit. When students have completed the test, they will return all the tests and answer sheets to the team envelope, and they will sit quietly until everyone has finished the test. Only one test from the group's envelope will be randomly selected and subsequently scored.

The concepts addressed on the tests can be found in most middle school and introductory textbooks for the study of technology. Despite the prominence this content in contemporary curricula, the knowledge base for problem solving and design has proven to be ambiguous to many contest participants in recent years. Therefore, teachers might want to note the following sampling of topics when preparing students for the competition.

Definition of Design

- A goal-directed problem solving activity
- Developing the optimum solution to a problem within a given set of parameters
- An imaginative jump from a present fact to future possibilities
- Creating something new and useful
- Respect for life, aesthetics, technology, and efficiency

The Basic Design & Problem Solving Process

- Identify and Analyze the Problem (examine a problematic situation, develop an operational definition of the problem, identify important considerations or specifications that need to be accounted for during the problem solving process)
- Gather Information (develop a list of questions that need to be addressed to solve the problem, identify potential information sources, gather the information needed to solve your problem)
- Generate Alternative Solutions (think freely and creatively in the spirit of brainstorming, generate a rich pool of alternative solutions from which a solution to the problem can be found)
- Select the Best Solution (evaluate the alternative solutions, identify their advantages and disadvantages, and select the best solution to the problem)
- Develop the Optimum Solution (refine the solution; develop renderings, working drawings, story boards, three dimensional models)
- Build and Test a Prototype (build a prototype solution to the problem, implement the prototype, determine if it meets the design specifications, make final modification and refinements)

- Present the Solution to Decision Makers (describe the solution to others through speech and with the aid of visual and empirical evidence)

Research and Development (creating a new product)

- Research (identifying the problem, gathering information)
- Development (developing preliminary designs, selecting and refining the design)
- Engineering (specifying the design, building and testing a prototype, presenting the design to management)

Tools & Techniques for Design

- Brain Storming (thinking freely, generating and recording ideas, reserving judgments)
- Visualizing (creating mental pictures)
- Drawing (recording ideas in the form of images)
- Modeling (making three dimensional or mathematical representations)

Thumbnails & Renderings

- Thumbnail Sketches (small, simple, rough, no details, drawn quickly, used to store, visualize, compare, and present ideas)
- Renderings (detailed and lifelike drawings used to present a refined concept for a new design)

Mock-up & Prototypes

- Paste-up Mock-ups (simple 3 dimensional representations, often made to scale, made out of modeling materials like paper, cardboard, or foam)
- Appearance Mock-ups (look real from a distance, made out of modeling material like clay or styrofoam, no working components)
- Hard Mock-ups (looks real, made out of the same materials as the final product, do not include any internal working components)
- Prototypes (working products, first product of its kind, used to test the design)

Product Design Principles

- Function (does it work)
- Aesthetics (does it look pleasing to the eye)
- Structure (is it put together well)
- Economy (is it worth the cost, will it be profitable)
- Integrity (is it ethical: fair and appropriate)
- Ergonomics (does it work in harmony with human anatomy)

Related Design Concepts

- Imitation (copying an existing device or process)
- Adaptation (modifying an existing device or process for a new application)
- Innovation (improving an existing device or process with a new technology)
- Invention (creating a completely new device or process)

Definition for Structures (material configurations designed to carry and distribute loads and designed to withstand external forces)

Basic Requirements for Structures

- Carry the loads for which they are designed
- Resist external forces (e.g., wind, gravity)
- Will not collapse in use
- Hold various parts in their correct position

Concepts Associated with Structures

- Tension (forces that pull on atomic bonds within materials)
- Compression (forces that squeeze atomic bonds within materials)
- Torsion (forces that produce a turning or twisting action within materials)
- Shear (forces that try to make one part of a structure slide past another)
- Triangulation (fastening structural elements into triangular frames that will withstand tension and compression forces)

Structural System Elements

- Struts (a part of a structure that carries a compression load)
- Ties (a part of a structure that carries a tensile load)
- Columns (vertical members that transmit loads to the foundation of a structure)
- Beams (horizontal members that carry and distribute loads at right angles to their longitudinal axis within structures)

Applications for Structures

- Facilitating shelter (e.g., houses, sky scrapers, office buildings)
- Spanning geographical obstacles (e.g., bridges)
- Carrying loads (e.g., power line pylons, antenna towers, water towers, furniture)

Definition for Mechanisms (transmitting energy through the motion of simple and compound machines)

Concepts Associated with Mechanism

- Conservation of energy
- Energy cannot be created or destroyed.
- Energy can only be converted from one form to another
- You cannot get something for nothing
- Mechanical Advantage (ratio of two forces: effort and load or input and output)
- Velocity Ratio (ratio of two distances: distance traveled by the input force to the distance travel by the output force)

Basic Types of Mechanisms

- Linear Motion Mechanisms
  - Levers (class 1, class 2, class 3, bell crank)
  - Linkages (rotary, fixed pivot, push-pull, equalizing, parallel motion)
- Rotary Motion Mechanisms (belts & pulleys, gears, chains & sprockets)
- Compound Motion Mechanisms (cams, cranks, screws)

Mechanical System Elements

- Input Force & Motion
- Mechanical Transducer (mechanism)
- Output Force & Motion

Application for Mechanisms

- Lifting Objects
- Changing Direction
- Changing Speed
- Increasing the Ability to do Work

Laboratory Portion

Each team will be given a technical problem that has more than one viable solution. Their challenge will be to develop the optimum solution to the problem within a given set of constraints. These constraints will include specific design specifications, material restrictions, and a time limitation. To solve the problem, each team will need to analyze the problem, generate alternative solutions to the problem, select and refine the optimum solution, construct a prototype of their solution, and test their solution to the problem.

The problem solving process will start with an examination of a problematic situation. The problem will be presented to students in the form of a **design brief**. A design brief is a short narrative that describes a situation, which is usually hypothetical, that features a problem that needs to be solved. In addition to describing a problem, each design brief will provide students important contextual information that will add meaning to the learning experience. It will also define the important design considerations or specifications that need to be accounted for during the problem solving process. Lastly, the design brief will encourage students to think creatively, allow for a variety of alternative solutions, and initiate the problem-solving process.

Each team will also be required to develop a design portfolio that will be included in the judging process. The term **design portfolio** is a generic name for a number of formats that can be used to encourage students to document their problem-solving process. The primary purposes of the design portfolio are to:

- record the students' ideas which can assist them in planning and executing the problem-solving process, recalling important information and problem specifications, and developing the best solution to the problem.
- show a lineage of the students' progress from the inception of the problem to its solution.
- document the students' thought processes and provide concrete evidence of what the student has learned.
- enable the judges to assess how well the student understands the important concepts associated with the problem as well as the problem-solving process itself.

During the judging process emphasis will be placed on the number and variety of ideas generated, the quality of the anecdotal notes documenting the salient features of each design, a final drawing that combines the team's best ideas into one composite design, the things that they like best about their design, the things they learned during the design process, and what they would do different if they were to do it again.

When students have finished their design, each team will be asked to demonstrate or present their solution to the problem posed. Students participating in the structures section will put their structures on the test fixture and add a load until it breaks. In the mechanisms section students will use their mechanism to perform a given task (e.g., move a given load from one location to another). Lastly, students participating in the product design section will make a three minute presentation describing the important features of their design.

Preparing Students for the Competition

The problem solving contest is based on current practices in technology education curriculum and instruction. Therefore, one can find an abundance of resources on the World Wide Web, *The Technology Teacher* (the journal of the

International Technology Education Association), textbooks, and curriculum guides. The following abstracts describe units of instruction that teachers can implement prior to the competition to prepare their students for one of the problem solving sections.

Product Design

Explain how products are created during the research and development process. Include major processes like identifying and analyzing a problem or opportunity, developing preliminary designs, selecting and refining a design, making and testing a prototype, and proposing the final design to management. Divide the class into small product design teams. Ask each team to identify a problem or opportunity that can be addressed with a new product. Using simple drawing tools and graph paper, have each team develop a variety of product designs that will address their problem. When they have finished, ask each team to evaluate their design based on function, appearance, and feasibility. Have students select and refine their best design in the form of a rendering and/or mock-up; use their rendering or mock-up to develop a set of plans, and use the plans to build and test a prototype product. Lastly, have each team present their design to the class and ask the class to select the best design for the final product. Discuss why research and development is one of the most important steps in the manufacturing process.

Structures

Discuss how technology is used to build structures that contribute to our quality of life. Introduce students to concepts like load, tension, and compression and how they apply to the building of pathways, structures, and buildings. Provide students pictures of common structures (e.g., antenna towers, sky scrapers, locks and dams, tunnels, trusses, bridges, power line pylons). Working groups, have students analyze their assigned structure, label the members that are under tension and compression, and describe how it carries and distributes its load. Explain how the class will experience construction technology by designing, building and testing model structures. Divide the class into small groups and assign each group a problem statement describing the specifications for a model structure (e.g., length, width, height). Demonstrate how to use simple tools and easy-to-work materials (e.g., paper, cardboard) to build a model structure. Have each team work cooperatively to design, build, and test a small model structure. In the context of friendly competition, place each structure in a fixture and apply a load to a predetermined point on the structure. Increase the load until the structure fails. Have students analyze how each structure carried and transferred the load and why it failed. Ask students to identify and discuss the features that contribute to a structure's integrity. Discuss the positive and negative impacts of construction technology on society and the environment.

Mechanisms

Introduce students to the various simple and compound machines used to transmit energy mechanically. Discuss how concepts like mechanical advantage, gear ratio, and torque apply to mechanical systems. Demonstrate how to use simple tools and common mechanical components (e.g., levers, linkages, pulleys, belts, gears, chains, sprockets) to build and test a mechanism. Have students in small groups build, test, and evaluate mechanical systems that address given energy transmission problems. Each problem should be expressed in an industrial context and feature challenges like converting a linear motion into a rotary motion, converting a clockwise motion into a counter-clockwise motion, and enlarging a given motion by a factor of four. Using a bicycle as an example, discuss the positive and negative impacts of mechanisms on society and the environment.

Students Need To Bring (all categories):

Pencil	Scale	*NOTE: Teams must compete in the contest that they register for.*
Safety Glasses	T-Square and Triangle	*(For example, a team registered in the Product Design category cannot*
Calculator	Xacto-Knife	*compete in the Mechanical category.)*