Information-processing Model of Human Problem Solving

Information-Processing System used by the human mental system in solving any type of problem
Information-processing Model of Human Problem Solving

- **Types of Knowledge that might be in a chunk of information:**
  - **General knowledge**
    - Information that most people know and apply without regard to a specific domain
      - “red is a color.” “4 is bigger than 3.”
    - Gained through everyday experiences and basic schooling
  - **Domain Specific Knowledge:**
    - Information on the form or function of an individual object or a class of objects
      - Bolts are used to carry shear or axial stress
      - The proof stress of a grade 5 bolt is 85 kpsi.
    - Gained from study and experience in the specific domain
      - It may take about 10 years to gain enough specific knowledge to be considered an expert in a domain
  - **Procedural Knowledge:**
    - The knowledge of what to do next
      - If there is no answer to problem X, then decompose X into two independent subproblems of x1 and x2 that are easier to solve.
    - Gained mostly from experience
    - Required for solving mechanical design problems
Information-processing Model of Human Problem Solving

• Short-Term Memory (STM):
  – Corresponding to RAM in a computer
  – Main information processor in the human brain
  – Information chunks can be processed in about 0.1 sec.
    • Processing implies such actions as comparing one chunk of information to another, modifying a chunk (decomposing or assembling), etc.
  – The more memory is used to solve harder problems.
  – “Magical Number Seven, Plus or Minus Two” Capacity of the short-term memory
    • Only two or three chunks can be compared at one time due to limits in short-term memory capacity.

• Long-Term Memory (LTM):
  – Permanent retention of information (Disk storage in a computer)
  – Unlimited capacity
    • No documented case of anybody’s brain becoming full regardless of the head size
  – Fairly slow in recording information (2-5 minutes to memorize a single chunk of info)
  – Speedy recovery of information, although retrieval time depends on the complexity of the information and the recentness of its use.
  – Information can be retrieved at different levels of abstraction, in different languages, and with different features.
    • Human memory is powerful in matching the form of the data retrieved to that which is needed for processing in the short-term memory.

• Control of the Information Processing System:
  – enables us to encode outside information obtained through our senses or retrieve information from LTM for processing in STM.
  – When completed manipulating the info, the controller can store the results in the LTM or in the external environment by describing it in text, verbally, or in graphic images.
Implications of the Information-processing Model

- The size of STM is a major limiting factor in the ability to solve problem.
  - To accommodate this limitation, breakdown problems into finer and finer subproblems until we can “get our mind around it”
    - in other word, manage the info in our STM
  - Human designers are quite limited although our expertise about the constraints and potential solutions increases and our configuration of chunks becomes more efficient as we solve problems.
  - These limitations would preclude our ability to solve complex problems.
Mental Processes that Occur during Design

• Understanding the problem:
  – A problem is understood by comparing the requirements on the desired function to information in the long-term memory.
  – Every designer’s understanding of the problem is different, we need to develop a method to ensure that the problem is fully understood with minimal bias from the designer’s own knowledge.

• Generating a solution:
  – Use the information stored in LTM that meets the design requirements.
  – If no solution found from LTM, then use a three step approach
    • Decompose the problem into subproblems
    • Try to find partial solutions to the subproblems
    • Recombine the subsolutions to fashion a total solution
  – Creative part of this approach is in knowing how to decompose and recombine cognitive chunks

• Evaluating the solution:
  – Evaluation requires comparison between generated ideas and the laws of nature, the capability of technology and the requirements of the design problem itself.
  – Evaluation requires modeling the concept to see how it performs.
  – The ability to model is usually a function of knowledge in the domain.

• Deciding:
  – A decision is made at the end of each problem-solving activity to accept the generated and evaluated idea or to address another topic that is related to the problem.

• Controlling the design process:
  – Path from initial problem to solution seemed random.
Problem-Solving Behavior

• A person’s problem-solving behavior affects how problems are solved individually and has a significant impact on team effectiveness.

• Four Personal-Problem Solving Dimensions (or styles):
  – Introvert:
    • Solve problem internally (reflective); a good listener; think and speak; enjoy having time alone for problem solving
  – Extrovert:
    • Sociable; tend to speak and think
    • About 75% Americans and 48% of engineering students and executives
  – Objective:
    • Logical, detached and analytical
    • Taking objective approach to make decisions
    • 51% of Americans, 68% of engineering students, 95% of top executives
  – Subjective:
    • Make decisions based on an interpersonal involvement, circumstances, and the “right thing to do”

• Please make sure to read section 3.3.6 carefully for better design team activities.
Characteristics of a Creative Designer

• Problem solving involves:
  – Understanding the problem, generating solutions, evaluating the solutions, deciding on the best one, and determining what to do next

• Criteria of Creative Solution:
  – It must solve the design problem.
  – It must be original.
    • Originality and creativity are assessed by society.
Characteristics of a Creative Designer

• Creativity in relation to other Attributes
  – Intelligence: no correlation with creativity
  – Visualization Ability:
    • Creative engineers have good ability to visualize, to generate and manipulate visual images in their head.
    • The ability to manipulate complex images can be improved with practice and experience.
  – Knowledge:
    • A person must have knowledge of existing products to be a creative designer
    • A firm foundation in bioengineering science is essential to being a creative biomechanical designer.
  – Partial Solution Manipulation: important attribute
  – Risk Taking: certainly required
  – Conformity: Creative people tend to be nonconformists.
    • Constructive nonconformists take a stand because they think they are right and might generate a good idea.
    • Obstructive nonconformists take a stand just to have an opposing view and will slow down the design progress.
  – Technique:
    • Creative designers have more than one approach to problem solving.
  – Environment:
    • Higher creativity when the work environment allows risk taking and nonconformity and encourages new ideas.
  – Practice:
    • Creativity comes with practice.
    • Practice enhances the number and quality of ideas.
Creative Designer

• A creative designer is a:
  – Visualizer;
  – Hard worker; and
  – Constructive nonconformist with knowledge about the domain and ability to dissect things in his or her head

• Good News:
  – Designers with no strong natural ability can develop creative methods by using good problem-solving techniques to help decompose the problems in ways that maximize the potential for understanding it, for generating good solutions, for evaluating the solutions, for deciding which solution is best and for deciding what to do next
  – A design project requires:
    • much attention to detail and convention;
    • demands strong analytical skills; and thus
    • People with a variety of skills.
  – There are many good designers who are not particularly creative individuals.
Engineering Design Team

• A team is a group of people working toward a common understanding.
• Team vs. Individual Problem Solving
  – There are social aspects of team work.
  – Each team member may have different understanding of the problem, different alternatives for solving it, and different knowledge for evaluating it. (more solutions but also more confusion)
• Team Goals:
  – A small number of people with complementary skills who are committed to a common purpose, common performance goals and a common approach for which team members hold themselves mutually accountable are required for an effective team.
  – Team members must:
    • learn how to collaborate with each other, i.e., to get the most out of other team members.
    • Comprise to reach decisions through consensus rather than by authority.
    • Establish communications.
    • Be committed to the good of the team.
• Team Roles:
  – Organizer; Creator; Resource-investigator; Motivator; Evaluator; Team worker; Solver; Completer (finisher or pusher)
• Building Team Performance:
  – For developing productive teams;
    • Keep the team productive
    • Select team members on the basis of skills in both primary and secondary roles
    • Establish clear rule of behavior
    • Set and seize upon a few immediate performance-oriented goals.
    • Spend time together.
    • Develop a common understanding
An Ideal Flow Chart of Activities During Design Process
What initiates a Design Project?

• Need for a New Design:
  – Market:
    • About 80% of new product development is market-driven.
    • Assessment of the market is most important in understanding the design problem because there is no way recover the costs of design and manufacture without market demand.
    • Incorporation of the latest technology can improve it perception as a high quality product.
  – New product idea without market demand
    • To use new technologies whose development requires an extensive amount of capital investment and possibly years of scientific and engineering time
      – High financial risk but greater profit due to uniqueness
    • Examples of successful products: sticky notes; Walkman

• Need for Redesign
  – By market demand for a new model
  – Desire to include a new technology
  – Fix a problem with an existing product
  – Redesign process can be applied to the subproblems that result from the decomposition of a higher-level system.
Overview of the Design Process

• Project Planning:
  – to allocate the resources of money, people, and equipment to accomplish the design activities:
  – Planning should precede any commitment of resources although requiring speculations about the unknowns
    • Easier to plan a project similar to earlier projects than to plan a totally new one
  – Plans are often updated whenever unknown demands become certain with the progress of design project

• Specifications Definition:
  – Goal is to understand the problem and to lay the foundation for the remainder of the design project.
    • Identify the customers: Generate the customer’s requirements: Evaluate the competition: Generate engineering specifications: Set targets for its performance
  – Design Review:
    • formal meeting for progress report and design-decision making

• Conceptual Design:
  – To generate and evaluate the concepts for the product
    • Generate concepts based on the defined specifications for developing a functional model of the product
    • Evaluate concepts by comparing the concepts generated to the targets for its performance
  – Design Review

• Product Development:
  – Evaluate the product for performance, cost, and production
  – Make product decisions
  – Documentation and Communication
    • BOM (Bill of Materials), Drawings, etc.

• Product Support:
  – Support for vendors, maintenance of engineering change, customer, manufacturing and assembly, and retirement of the product
Why Do We Have to Follow The Design Process Techniques?

• Paradox:
  – Techniques in the design process may imply “RIGIDITY” whereas the creativity implies “FREEDOM.”

• Following the techniques in the design process helps the designers develop a quality product that meets the needs of the customer by several ways:
  – Eliminating expensive changes later
  – Developing creative solutions to design problems systematically
    • Creativity does not spring from randomness.
    • “Genius is 1 percent inspiration and 99 percent perspiration.”
    • The inspiration for creativity can only occur if the perspiration occur early is properly directed and focused.
    • The techniques that make up the the design process are only an attempt to organize the perspiration.
  – Forcing documentation of the progress of the design (record of the design’s evolution) that will be useful later in the design process.
Design Process Examples

Simple Process

1. Understand the problem
2. Evaluate the product
3. Document the result

Complex Process

1. Develop specifications
2. Generate concepts
3. Evaluate concepts and decide on best one
4. Evaluate for performance, manufacture, assembly, and cost
5. Document the result
Communication during the Design Process

• Design Records:
  – Importance of documents in design file:
    • To demonstrate the state-of-the-art design practices
    • To prove originality in case of patent application
    • To demonstrate professional design procedures in case of a lawsuit
  – Design Notebook:
    • A diary of the design tracking the ideas development and the decision made in a design notebook
      – Name; Affiliation; Title of the problem; Problem Statement; and all sketches, notes and calculations that concerns the design
    • A design notebook sequentially numbered, signed and dated pages is considered good documentation whereas random bits of information scrawled on bits of papers are not.
      – Good evidences for legal purposes (patent or lawsuit) as well as a reference to the history of the designer’s own work

• Documents Communicating with Management:
  – Needed for periodic presentations to managers, customers, and other team members for design review
  – Regardless of its form (oral or written);
    • Make it understandable (consider the recipients’ level of knowledge about the design problem)
    • Carefully consider the order of presentation (whole – parts – whole: 3-step approach: gradual introduction of new ideas)
    • Be prepared with quality material (good visual and written documentation; following the agenda; being ready for questions)

• Documents Communicating the Final Design:
  – Material describing the final design, e.g, Drawings (or data files) of individual components and of assemblies
  – Written documentation to guide
    • manufacture, assembly, inspection, installation, maintenance, recruitment, and quality control
Team Project

- Select an original design problem to solve throughout the remainder of the course.
  - The problem should concern biomechanical devices in which some of the design team members have some knowledge or training.
  - The final product will be data from analyses and evaluation and final drawings, not an actual hardware.

- Design Team Activity:
  - Each student should start gathering the design ideas immediately and recording the ideas in the design notebook.
  - Start the team meeting ASAP for:
    - Organization of the team
    - Planning the design process to finish the project by the end of April.
  - Each team will present their design project in May.

Any discussion about the design project with the instructor is welcome.