Chapter 2
Organizing Knowledge for Instruction

What is intelligence? What do we know about knowledge? Are design and technological knowledge unique? Do different types of knowledge demand different organizations? How can we employ cognitive skills in the resolution of technological problems? This chapter provides an introduction to current theories of intelligence and the organization of knowledge with an emphasis on instructional organization. We will discuss learning theories and theories of cognition in Chapter 6. In the previous chapter we acknowledged that despite the proliferation of communication and information technologies, communication skills for most people have atrophied. At the same time this proliferation of new technologies has created conditions for what we experience as information overload. For this reason it is extremely important that teachers develop effective skills and techniques for the communication, organization and presentation of information and knowledge. It is essential that teachers develop working understandings of current theories of knowledge and skills. Our understandings of technological knowledge and literacy along with the theories that we act on determine the way we teach about, through and for design and technology. Current theories of intelligence, or cognitive pluralism, and the organization of knowledge are fundamental to effective instruction. This chapter builds on the basic communication and organization techniques provided in Chapter 1. The effective organization of instruction requires the effective organization of knowledge.

Intelligence

Intelligence is no longer merely associated with the reasoning skills necessary to successfully complete an intelligence test. The twentieth century began with very narrow notions of intelligence that differentiated among people in extremely biased ways. According to Binet-Simon intelligence exams, students were found to be imbeciles, morons, retarded, sub-normal, normal or geniuses according to their intelligent quotient or IQ. Even while scientists argued that intelligence, or a "general mental adaptability to new problems and conditions of life," was both innate and environmental, most of the scientists leaned toward the genetic side rather than the cultural side (Petrina, 2000). Not very surprisingly, many students from poor and working class families were below average intelligence. Students found to be below average intelligence were believed to be stupid for life. By the 1960s however, both the exams and the scientists were found to be racially biased. One result of research into intelligence practices was that intelligence is no longer measured in terms of exams and IQs. Fairly recent changes in cognitive science have led researchers to re-think customary notions. In effect, intelligence has been democratized. Everyone is intelligent in some way. Intelligence can generally be defined today as "the capacity to solve
problems or to fashion products that are valued in one or more cultural settings" (Gardner & Hatch, 1989). The difference between this and earlier definitions is the qualification that connects intelligence to specific cultural settings. Intelligence theories continue to suggest that intelligence results from an interaction of biological and cultural forces and functions.

According to Howard Gardner (1983, 1993), each and every human has the capacity to be intelligent in one or a number of eight areas that correspond with ways of resolving problems. These capacities are: Bodily-kinesthetic, Existential, Interpersonal, Intrapersonal, Musical, Logical-mathematical, Linguistic, Naturalist and Spatial. Most of us in technology directly involve bodily-kinesthetic, logical-mathematical and spatial capacities in very complex ways. You could say that we have developed high levels of intelligence; we have high levels of bodily-kinesthetic, logical-mathematical and spatial intelligence. This is not to say that these three intelligences are the only significant intelligences for practice in design and technology. In fact, teaching typically requires high levels of existential, interpersonal and intrapersonal intelligence, or as we will explain in the next chapter, high levels of emotional intelligence. When we are creative, as we will discuss in Chapter 5, we integrate a wide range of intelligences to the resolution of problems.

**Howard Gardner’s Multiple Intelligences**

**Bodily Kinesthetic Intelligence** - the ability to use mental abilities to coordinate one’s Own or others’ physical movements.

**Existential Intelligence** - the ability to explore philosophical dimensions of being, existence and meaning.

**Interpersonal Intelligence** - the ability to communicate and converse with others on social terms. Expressive or persuasive articulation and communication of insights and thoughts.

**Intrapersonal Intelligence** - the introspective ability understand one’s own feelings and motivations. Expressive articulation and communication of feelings.

**Linguistic Intelligence** - the ability to effectively manipulate language to express oneself rhetorically or poetically. Use of language and narrative as a means to the memory of information.

**Logical/Mathematical Intelligence** - the ability to detect patterns, reason deductively and think logically. Often associated with math, science and technology.

**Musical Intelligence** - the ability to recognize and compose musical pitches, rhythms and tones. (Auditory functions are necessary for pitch and tone but not necessarily for rhythm)

**Naturalist Intelligence** - the ability to sense natural cycles and rhythms and to relate to the natural world. The ability to discriminate among (animals, plants) as well as sensitivity to features of the natural world (clouds, cycles). Sensitivity to natural processes.

**Spatial Intelligence** - the ability to create and manipulate mental images to find and solve problems. Not necessarily limited to visual domains.
Why ought we consider Gardner's theory of Multiple Intelligences (MI) to be a breakthrough? Is it a tenable theory? Does it resonate with your own experiences? One of the primary reasons MI is such a breakthrough is that it validates practice in design and technology. MI puts the ball back into the central offices of schools and governments. No longer is it sufficient to provide for merely one or two intelligences in schools. No longer is it sufficient to orient an entire educational system toward one or two intelligences. The pressure is now on the schools to accommodate and nurture a range of intelligences that were previously neglected or ignored. MI also makes a case for attending to a range of learning styles in the schools. Students learn differently, as we will explain in a later chapter.

The trend in intelligence theory is toward cognitive pluralism, or the recognition of a wide range of expressions of knowledge. Cognitive pluralists, such as Gardner and Robert Sternberg, recognize that our traditional observations of intelligence were quite limited. Pluralists theorize an inclusive range of expressions of intelligence that recognize the ways that the head, heart, hand and feet are "intelligent" and learn together. If cognitive pluralism recognizes multiple ways of knowing, then emotional pluralism recognizes different ways of feeling and kinesthetic pluralism embraces ways of moving to express skill. In chapters 3 and 6 we will explore cognition, emotion and action in more depth.

Like Gardner, Sternberg revised traditional notions of intelligence by arguing that there were multiple intelligences. Sternberg also responded to Gardner and argued that seven (there are now nine) intelligences were too many and weakened the very notion of intelligence. For Sternberg, there are three modes of intelligence that cover the spectrum of Gardner's MI. Sternberg's Triarchic Theory validates design and technology educators in the same way that MI does. The new theories of intelligence recognize the variability among populations and acknowledge the range of capacities that can be developed in education.

<table>
<thead>
<tr>
<th>Robert Sternberg’s Triarchic Theory of Intelligence</th>
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<tr>
<td><strong>Analytical Intelligence</strong>- How individuals relate to their internal worlds; Analogic problem solving.</td>
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<tr>
<td><strong>Creative Intelligence</strong>- Insight, synthesis and the ability to react to novel stimuli and situations.</td>
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<tr>
<td><strong>Practical Intelligence</strong>- Ability to grasp, and solve real-life problems in the everyday jungle of existence.</td>
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**Knowledge**

Our views of intelligence were changing at the same time that our views of knowledge were changing during the 1960s and 1970s. Current perspectives on knowledge helped us to dispense
with the notion that knowledge is information, or an accumulated database that can be applied when the circumstance arises. Here, knowledge is passive and in storage for potential uses. Knowledge is much more dynamic, and generative rather than applicative. Knowledge generates action, and of course, action or experience generates knowledge. Knowledge is both the process and product of creative action. We will address learning theory and the generation of knowledge per se in Chapter 6. In this chapter, we stick with the issues of articulating and organizing knowledge for instruction. To make a transition in education from knowledge as information to be transmitted from teacher to students, to knowledge as dynamic, we have to understand the types of knowledge that are fundamental to technology studies. We have to understand how knowledge is articulated and integrated into experience.

In the first chapter, we introduced the cognitive domain, which is a model of how knowledge is articulated from basic memorization of information to the application and evaluation of knowledge. The lowest level of the cognitive domain involves rote and basic memorization and information. Knowledge is articulated here as simple bits of information. Knowledge is articulated at the next level as a translation of one form of facts to another. This requires comprehension. The third level involves the application of knowledge to concrete challenges. Knowledge is articulated at this level as laws, models and procedures. The next two levels involve the analysis and synthesis of knowledge. Knowledge is articulated at these levels as theories, plans of action, designs and inventions. At the highest level, we are able to pass judgment on the theories, plans of action, designs and inventions articulated at the levels of analysis and synthesis. Knowledge is articulated at this level as schemes for evaluation and critiques.

Think about how loosely we qualify types of knowledge: artistic knowledge, practical knowledge, scientific knowledge, tacit knowledge, technical knowledge and so on. Inquiring into types of knowledge involves the work of epistemology and praxiology. Read the definitions of terms related to knowledge. In design and technology, a wide range of different types of knowledge is used, as listed in the table below. In the next few sections, we will reduce the types of knowledge that we deal with to propositional and procedural knowledge. For all intents and purposes, procedural knowledge will refer to technical knowledge and procedural knowledge when added to propositional knowledge will refer to sociotechnical knowledge. We generally define procedural knowledge as knowledge of directions or procedures and propositional knowledge as knowledge of conditions. In design and technology, procedural knowledge is called technical knowledge and propositional knowledge is called sociotechnical knowledge. Both are necessary for design and technological practice.
Defining Knowledge

**Epistemology** - study of cognitive processes and knowledge. The problem of epistemology is how to know the world.

**Praxiology** - Study of practical activity and knowledge. The problem of praxiology is how to change or create the world. A science of rational action and study of practical sciences (administration, design, engineering, medicine). Involves describing, classifying and appraising, or establishing norms for and evaluating efficiency of, practical action. The primary value of interest is efficiency, or rationality between means and ends.

**Know-How** - Combination of coordination, experience and proper sensitivity to the fitness of things (i.e., functional, aesthetic, etc), sensory skills and practical knowledge.

**Practical Knowledge** - Knowledge of situations. Know-how of the workings of intrapersonal and interpersonal problems in everyday life.

**Really Practical Knowledge** - Knowledge of situations, applications and implications. Practical and political understanding of procedure, place and the world. Knowing how, why and why not.

**Tacit Knowledge** - Knowledge that is embodied and difficult to impart or articulate.

**Technical Knowledge** - Knowledge of applications. Know-how of the workings of technical features. (Procedural knowledge)

**Sociotechnical Knowledge** - Knowledge of applications and implications. Combination of technical and sociopolitical, or procedural and propositional knowledge. Know how and know why.

**Propositional or Conditional Knowledge** - Knowledge of conditions. Knowledge of implications. Know that.


Traditionally, technical knowledge is emphasized in design and technology education and sociotechnical knowledge is ignored. Nevertheless, one of our responsibilities in the change from industrial education and educational technology to design and technology education is the incorporation of sociotechnical or procedural plus propositional knowledge into the curriculum. It is our responsibility to deal with the ethical-personal and socio-political dimensions of technology as well as with the traditional technical dimension.

Think about a technology that you will be dealing with in the schools, such as a hammer, a transistor or a specific piece of hardware. Are you prepared to teach both the applications and implications of this technology? Are you familiar with the history, sociology or psychology of this technology? Are you prepared to deal with the ecological issues or the role of this technology in workplace innovation? How will you prepare resources that deal with the propositional knowledge of specific technologies? Take Computer Aided Design (CAD) for instance (Petrina, 2003).
vast majority of instruction focuses on procedures or applications. Very little time is spent on conditions and implications of CAD. In the outlines below, technical or procedural knowledge is represented on the left and propositional knowledge on the right (Outline 2.1).

Outline 2.1. Procedural and Propositional Knowledge of CAD

I. Introduction
   A. CAD
   B. Components of CAD systems
      1. Hardware
      2. Software
   C. Operating Systems
   D. CAD user skills
   E. Data storage
   F. Data handling

II. CAD system interface
   A. Main menu
      1. Drawing editor
      2. Configuration
      3. Plotting
   B. Commands
      1. Drawing
      2. Tool
      3. Edit
      4. Set-up
      5. Block and Attribute
   C. Prototype drawings
   D. Simple geometric shapes
      1. Entity creation
      2. Plotting
   E. 2D CAD
      1. Layers
      2. Dimensions
      3. Plotting with layers

III. Symbol libraries
   A. Access
   B. Organization
   C. Slides

IV. Database Management
   A. Integration with CAD
   B. Databases (Dbase, Excel, etc.)

V. 3D modeling
   A. Wireframes
   B. Extrusions
   C. Surfaces/ Meshes
   D. Solids

VI. Design and Analysis

They reinforce each other. It is as important for a student to understand the ergonomics and psychology of CAD, as it is to understand how to create a wireframe model. Perhaps 60%-70% of time in technology studies labs and workshops ought to be spent on procedural knowledge.
and 30%-40% on propositional knowledge. More than anything else, this example lays out the argument for why technology studies teachers have to pay attention to both procedural and propositional knowledge and their relationships with reasoning abilities.

**Cognitive Skills: Reasoning**

Knowledge is articulated in various forms such as algorithms, concepts, directions, factlets, generalizations and strategies. How are these forms developed? How do we develop a series of generalizations from disparate facts and concepts? How do we create and test facts? How do we develop rules of thumb and strategies from different sets of directions? This is where the cognitive skills and the processes of reasoning enter into intelligence. We have developed cognitive skills or reasoning techniques for generating and testing knowledge. Of course, reasoning does not account for the generation of all knowledge. For example, intuition and spiritual revelation offer us ways of generating knowledge without reason. Nevertheless, the development of reasoning abilities is essential to design and technology. In some cases, knowledge in design and technology, like scientific knowledge, is rational and verifiable. The results are predictable. In other cases and when extended to social situations, this knowledge can be unpredictable. In some cases, we want to solve problems, in other cases we want to create and find problems. Sometimes we want to analyze and sometimes we have to synthesize. Designers and technologists need a range of abilities and skills that allow them to reason and learn from mistakes and successes. Students and teachers of design and technology need these same abilities and skills.

At times, students ought to engage in convergent reasoning and other times divergent reasoning. Drawing conclusions, generalizations and inferences is extremely important in design and technology but is also difficult. Drawing inferences and distinguishing commonalities from a range of different data involve the practice of convergent reasoning. Diversifying ideas and identifying differences from a range of data involve the practice of divergent reasoning. Both convergent and divergent reasoning have to be taught and practiced. Convergent reasoning often refers to synthesis while divergent reasoning refers to analysis. Activities such as brainstorming and sketching help students develop divergent reasoning skills. Choosing among alternatives and consolidating ideas into a single design help develop convergent reasoning skills. Although learning style research suggests that individuals have preferences for either convergent or divergent reasoning (see Chapter 4), technology requires that we develop skills for each. For instance, the ideation and problem finding processes of design requires that we diverge from initial ideas and the settling on a design requires that we converge on an eventual solution.
Cognitive Skills

Convergent Reasoning

- Synthesis
- Trial and Error
- Problem Finding and Solving
- Goal Setting
- Procedural Knowledge

Divergent Reasoning

- Analysis
- Experiment
- Problem Finding and Solving
- Brain Storming
- Propositional Knowledge

Deductive Reasoning

From generalizations to specifics. Deductive reasoning is the analogue of divergent reasoning. Typically associated with hypothesis testing in chemistry, engineering or physics, deductive reasoning has many applications in everyday life and learning. For example, if a technician knows Ohm’s Law or other electrical principles, s/he can deduce and isolate problems to specific components or parts of a circuit (Fig. 2.1). We also deduce directions and procedures for working around electricity from our general knowledge of electrical danger related to shock.

![Figure 2.1. Ohm's Law and a Simple Series Circuit](image)

Inductive Reasoning

From specifics to generalizations. Inductive reasoning is the analogue of convergent reasoning. Typically associated with theory building in biological, earth or social sciences, inductive reasoning has many applications in everyday life and learning. For example, if a tire manufacturer finds that in twenty isolated cases there were blowouts of tires at highway speeds, the
manufacturer will generalize that there is likely to be more blowouts and recall that brand of tire. In much of technological practice, inductive reasoning deals in probabilities. Decisions are made based on the probability of this or that happening or being the case. Chances are taken based on calculations of probability. In the case of the tires, while twenty blowouts in 500,000 tires is a low percentage, the tire manufacturer would rather error on the side of caution than suffer a lawsuit.

Deductive and inductive reasoning have crucial applications in technology studies. For example, we may provide students with Ohm’s Law and a circuit and ask them to test the relationships among current, resistance and voltage. Or we may provide them with a number of circuits, but not the Ohm’s Law, and ask them to discover relationships among current, resistance and voltage. In the first instance, deductive reasoning, we have organized knowledge for the students. We have given them the basic organizer of our knowledge of relationships among three primary forces of electricity. In the second instance, inductive reasoning, we are asking the students to organize knowledge of electricity. We gave them the components of a basic electrical system but not the organizer of the relationships among forces. Yet, in both cases the result was the development of cognitive skills and organization of knowledge.

**Articulating Knowledge**

How do we articulate what we know and what we want students to know? How can we help students to articulate what they know? Procedural knowledge is typically articulated as directions, rules of thumb and strategies. Propositional knowledge is typically articulated as facts, concepts and generalizations. When we teach it is necessary to organize our knowledge. We must learn how to provide accurate and clear directions and how to describe the facts and concepts related to our topics. To be an effective teacher we must be articulate with knowledge of design and technology.

**Procedural Knowledge- Know how**

Procedural knowledge is knowledge of procedures, dealing with episodic memory. For example, we remember the episode of scanning and recall the procedures to scan an image. The movement through procedural knowledge ought to be from directions to strategies. Procedural directions and order define procedural knowledge. We ought to help students develop algorithms or rules of thumb for procedures. For example, we will provide specific procedural directions for students learning to use an electric drill. We will then introduce another power tool, such as a sabre saw, and provide specific directions. But we want students to develop rules of thumb for using power tools, such as do not make adjustments when the tool is plugged in. Or clamp materials in place when using power tools. And ultimately we want students to develop overall strategies for using power tools. We want them to develop a strategy for the entire set-up, use and clean-up. We can
test algorithms and strategies with the details of directions. From algorithms we ought to develop strategies. A strategy is a general plan of action that ought to be flexible enough to guide a range of procedural practices. Strategies are a form of metacognition, reflecting an awareness of how one proceeds through procedural knowledge.

- **Directions** - How to do this?
- **Algorithms** - Rules of thumb established?
- **Strategies** - General plan of action established?

Procedural knowledge is typically organized as step-by-step directions that takes the form of step 1) do this, step 2) do this and so on. Procedures are basically if-then rules: *If* the condition specified is satisfied, *then* the next step in the action is carried out. In regards to safety procedures, if the conditions for safe use of a machine are satisfied, then the machine is used. For procedural knowledge to be learned, procedures must be rehearsed, both cognitively and physically. We create procedural directions, guidelines and rules for completing tasks and procedures that take the form of "do this" but "do not do this." There is an explicit order to directions and, in most cases, steps cannot be substituted one for the other. In many cases, if we transpose steps, the process will fail and injury or harm may come to the person completing the procedure. Guidelines and rules cannot be crossed. Recall a time when you were given directions for finding your way to an unfamiliar location. With poor directions, you most likely got frustrated and lost and asked for directions again. With clear, orderly directions you found your way. Procedural knowledge is basically analytical, linear and future-oriented. Procedural directions are derived from task analyses of activity (Chapter 8). In our case, directions are derived from a task analysis of technological activity.

Designers and technologists develop the habit of generalizing guidelines, rules and steps into rules of thumb. Over time and courses of action, directions and if-then rules become routine, habitual and automatic. Here, we recognize a situation as typical and respond consistently according to an estimated probability that our response will satisfy the conditions of the situation. A rule of thumb is a shortcut that allows us to circumvent or integrate redundant steps. Rules of thumb eliminate options for us, and shortcut the process of eliminating the same options time and time again. For example, when auto technicians confront a car that is backfiring, they will shortcut a series of steps and zero in on the backfire as an ignition-timing problem. The student technician will develop this backfiring rule of thumb only after s/he has diagnosed a number of vehicles using
the directions for diagnosing erratic and sluggish performance. Rules of thumb are organized as guidelines that take the form of "if this is the case, then do this." In other words, if we recognize a situation as this, then we ought to respond in this way. That expert technician will have a strategy, or organized rules of thumb, for trouble-shooting and maintaining sluggish vehicles. Strategies anticipate what situations will be confronted and how these situations will be addressed. Strategies involve the organization of knowledge and resources for tackling a task or procedure, or in a word, metacognition.

In technology studies, our responsibility is to empower know-how, or procedural knowledge with propositional knowledge. Procedural knowledge ought to be used to inspire propositional knowledge. In Chapter 6, this premise of our learning theory is explained in detail. In the next section, we elaborate on propositional knowledge.

**Propositional Knowledge- Know why, what, when, who and where**

Propositional knowledge is knowledge of conditions and meaning, dealing with semantic memory. The movement through propositional knowledge ought to be from factoids or factlets to generalizations. Factlets are often considered to be infotrisia and somewhat useless without form or structure. We want students to organize facts and ultimately develop concepts and generalizations. A generalization is a synthesis of facts, concepts and phenomena that derives its significance from a range of places and practices and has applications in many concrete situations. A concept is a mental image conveyed through language. Concepts are typically abstract, and are subject to the expansion of meaning and delineation of detail as experience provides new applications and different contexts. Concepts and generalizations can be tested with the details of factlets and facts.

- **Factlets**- Bits of information about this?
- **Organized Facts**- Information organized?
- **Concepts & Generalizations**- General relationships articulated?

Propositional knowledge typically takes the form of facts, concepts and generalizations that have either a psychological or logical organization. Propositional knowledge ultimately deals with relationships. Propositional knowledge is typically organized by classification, chronology and relationship. Picture a list of animals that has no order imposed upon it. We can derive order by organizing the list according to our values and preferences: animals we like and animals we dislike.
This would be a psychological organization. Or we can derive order by alphabetizing the list, by classifying into classes such as amphibians or ranking according to size. This would be a logical organization of knowledge. The order of things helps us to develop propositional knowledge represented in the form of concepts. Imagine a list of software programs that is ordered by application: game, graphics, spreadsheet, publishing and text. But we want to move our students from organized facts to concepts and generalizations. From our animation programs grouped in the graphics category, we derive the concept of modeling. For our students we could describe what modeling involves, why and when modeling is important and the industries where modeling is most often used. Our generalizations take the form of inductive inferences. For instance, after observing the practices of the major automobile manufacturers in the US over the past decade and the return to gas-guzzling engines, we can generalize that these manufacturers are more interested in protecting their market share than in clean air and energy conservation. We can say that procedural knowledge is technical knowledge and procedural plus propositional knowledge is sociotechnical knowledge.

**Integrating Knowledge**

We acquire procedural and propositional knowledge through observation, practice, reasoning and reflection. We articulate knowledge through algorithms, concepts, directions, facts, generalizations and strategies. We integrate knowledge into our experiences by constructing meaning and models, by shaping and organizing, and by internalizing and relating. Acquiring, articulating and integrating knowledge are active processes. When we confront a task that requires a procedure to complete, our mind attempts to construct a model of the task. When we confront facts our mind attempts to create meaning. We begin to integrate knowledge by constructing models and meanings. We reinforce the integration of models and meanings into our experiences by shaping directions into rules of thumb and organizing facts into groups and classes. One goal is to internalize knowledge and develop habits of procedural practice of design and technology. Another is to develop habits for routine access of the interrelationships among the facts and concepts of design and technological practice.

To develop knowledge of design and technology, students must actively integrate this knowledge into their experiences. They need time and opportunities to concentrate, practice and talk about what they are doing and required to do. Students need instruction in how to construct models and meaning, and shape and organize directions and facts in order to integrate what they learn into their experiences. These are design and technological practices that experts take for granted but novices find extremely difficult. It is not enough for teachers to merely provide directions and facts. There has to be movement in the realms of procedural and propositional knowledge.
Procedural Knowledge (Episodic memory)

- **Constructing Models** - We acquire procedural knowledge through directions and the eventual construction of models, rules of thumb, etc.
- **Shaping** - By re-shaping what we procedurally did into rules of thumb, we begin to integrate procedural knowledge into our routines.
- **Internalizing** - Ultimately, we want to internalize procedural knowledge by adopting and shaping new routines and strategies.

Propositional Knowledge (Semantic memory)

- **Constructing Meaning** - We acquire propositional knowledge through the construction of concepts, generalizations and meaning derived from facts.
- **Organizing** - By organizing what we propositionally know, we begin to integrate propositional knowledge into our established concepts and discourses.
- **Relating** - Ultimately, we want to establish relationships and connections among facts and concepts by actively constructing meaning and reorganizing this into generalizations.

Organizing Knowledge for Instruction

Knowledge must be organized for instruction. This point is crucial for any form of education. Think about some of your most frustrating experiences in education. There is a good chance that your frustration was due to either emotional and physical discomfort or disorganization. And if the reason was disorganization, you probably experienced a disorganization of knowledge. Think about the running joke of technical directions that we receive when we purchase something that has to be assembled or installed, or when we purchase a new software application. Most of us discard the directions because we trust our own abilities to trouble shoot and problem solve over the vendors' ability to organize knowledge. In most cases with vendors, we witness the disorganization of procedural knowledge rendering the directions they provide useless.

Think about your own organizational skills. Do you consider yourself to be highly organized? If the answer is no, you will have to discard any pretense that it is ok to be disorganized and commit to clear, concise organizations of knowledge for your students. It is not ok to be disorganized when it comes to knowledge and instruction. While our minds tolerate chaos and amazing amounts of disorganization, when it comes to knowledge our minds crave for order and connections.

In the previous sections, we addressed the forms that we use to articulate and integrate procedural and propositional knowledge. We saw that to articulate procedural knowledge we have to organize it into directions, and algorithms and for propositional knowledge we develop classification systems, concepts and generalizations. Yet by themselves these ways of organizing
knowledge are inadequate for instruction. There are several proven techniques for organizing knowledge for instruction. Mind maps are very effective for organizing propositional knowledge but have shortcomings for organizing procedural knowledge. Information sheets are also effective for communicating propositional knowledge. Procedure sheets, on the other hand, work in tandem with demonstrations for the conveyance of procedural, or technical, knowledge. When you organize knowledge for your students you are actually preparing *advance organizers*. You are organizing knowledge in advance of your students' internal organization of the same knowledge. Advance organizers are absolutely crucial to the conduct of technology studies.

**Propositional Knowledge in Technology Studies: Images**

**Mind Maps**

What is a mind map and why are they important? The reason why pictures are "worth a thousand words" is that they make use of a massive range of cortical skills: color, dimension, form, line, text, texture, visual rhythm and especially the imagination. Images are therefore often more evocative than words, more precise and potent in triggering a wide range of associations, thereby enhancing creative thought and memory. In technology, the organization of knowledge is impossible without the benefit of images.

Mind maps, sometimes called concept maps or semantic organizers, are literally images of our ideas. Mind maps help us to convey large amounts of information in simple ways. Mind maps convey information of relationships in ways that other conveyances cannot. Mind maps are visual organizations of relationships (Fig. 2.2).

*Figure 2.2. Mind Map of Paper Clip Uses*
In 1969, a classic study demonstrated the importance of visual information as an aid to memory. Mind maps are much more effective than lists in triggering our memory and generating ideas. Key words or "Basic Ordering Ideas" of mind maps act as triggers. Linear notes in the form of lists contradict the workings of the mind in that they generate an idea and then deliberately isolate it from the preceding and following ideas.

Mind maps harness the brain's tendency to function in gestalts or wholes and invite the addition of ideas to the key words on the mind map. They invite the brain to add in the beckoning areas. Once the mind is invited to associate anything with anything else, associations will almost instantaneously be found, especially when triggered by an additional stimulus. Mind maps are based on the logic of associations, not the logic of time (as in a list).

The Basic Ordering Ideas (BOI) in any mind map are those words or images that are the simplest and most obvious ordering devices. They are the key concepts, gathering the greatest number of associations to themselves. A good way to find these BOIs is to ask:

- What knowledge is required?
- What are my specific objectives?
- What are the most important seven categories in the area under consideration?

**Mind Map Techniques**

**Use Emphasis**
- Always use a central image
- Use images throughout your Mind Map
- Use three or more colors per central image
- Use dimension in images
- Use synaesthesia (the blending of the physical senses)
- Use variations of size of printing, line and image
- Use organized spacing

**Be Clear**
- Use only one key word per line
- Print all words
- Make line length equal to word length
- Connect lines to other lines
- Make the central lines thicker
- Make your boundaries ‘embrace’ your branch outline
- Make your images as clear as possible
- Keep your paper placed horizontally in front of you
- Keep your printing as upright as possible

**Use Association**
- Use arrows when you want to make connections within and across the branch pattern
- Use colors and codes

**Layout**
- Use hierarchy
- Use numerical order
Schematics

Mind maps are extremely important in technology studies. In fact, mind maps have more uses in technology studies than any other subject. However, the maps have their limits in communicating procedural knowledge. They are quite poor for this, unless in the form of a flow chart. Their primary value is in communicating propositional knowledge and symbols. Technology is often quite symbolic, and schematic. The language of technology is symbolic. Think of drafting and CAD. The use of abstract symbols conveys procedural knowledge. Symbols lend themselves to communication in technology because they are normally visual and a shortcut to conveying relationships or plans. Complex processes or systems can be easily described and depicted through symbols in a schematic. A schematic is a diagram that represents procedures, processes and relationships. For example, the schematic below shows the complex concept of refrigeration and thermostatic control in simple terms (Fig. 2.3).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{schematic.png}
\caption{Schematic of Refrigeration System}
\end{figure}

Schematics reduce the technology to simple forms, so to speak. They make knowledge visible—they un-box black boxes. In electronics, designers work directly from schematic to circuit board to component. In the same way, students learn to breadboard from a schematic and build electronic circuit boards and components from the breadboard. Schematics and blueprints rely on symbols, many of which are universal for technologists. Electronic and interior designers learn a wide variety of symbols that they communicate with. When an experienced designer looks at a schematic, s/he typically knows exactly what components are required and where they go. Schematics provide a diagram of active systems as well as static systems (Fig. 2.4, 2.5). Complex technologies, such as a ramjet engine for jets, can be described in schematic form. While a photo would be quite effective in its realism, it is not easy to find a clear photo of a cross section of the technology of interest.
Propositional knowledge of science that is central to technology is also effectively represented as a schematic (Fig. 2.5). For example, an airfoil is extremely difficult to describe but can be easily represented in diagrammatic form. Why do the wings of an airplane create lift? What is lift?

The Bernoulli principle underwrites the design of airplane wings, and is readily demonstrated in a lab (Fig. 2.6). To supplement the demonstration, a schematic of the principle would be extremely helpful. In the diagram, which depicts the Bernoulli experiment, we can see that the rate of air passing through the constriction of the tunnel increases, creating a low-pressure area. There is now a pressure differential, and the column of water in the middle rises in response to the drop in pressure. The water rises. The plane lifts.
Bernoulli Principle

Figure 2.6. Diagram of Bernoulli Principle

The schematic below shows a conceptual model of a truss (Fig. 2.7). The engineering forces and structures of the truss are clearly communicated in the diagram. The top and bottom beams carry main compression and tension forces. Diagonal elements transmit forces between beams. Forces change in these elements from tension to compression as the load traverses the bridge.

Figure 2.7. Diagram of Truss

How can we represent our knowledge of levers and the principle of leverage that undergirds many of our common hand tools? Are basic machines the basis of technology? Diagrams of the three classes of levers show the relationships among the fulcrum, or pivot point, the effort placed and the resistance incurred (Fig. 2.8). The relationships define the class of lever.

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Our reason for presenting the various schematics is to emphasize that the language of technology is symbolic and graphic. We can illustrate concepts and principles of technology so effectively because technology itself is actually illustrative of concepts and principles. Technology is the manifestation and representation of our ideas and knowledge.

While the language of technology is graphic, our propositional knowledge of technology is often communicated through words and numbers. The next two figures are simple taxonomy trees or systems diagrams. The first represents the "discipline" or a system of technology. The taxonomy tree, family tree or systems diagram effectively represents one way of analyzing and classifying technological knowledge (Fig. 2.9). Taxonomy trees are useful for mapping the conceptual aspects of technology. In the Chapter 1, we mentioned the value of thinking systemically and systematically about instruction. Taxonomy trees help us to think in terms of systems. The caution, however, is that as we map some essences or key components of a system, we risk ignoring others. In the following map of the technology discipline, for example, technical systems of technology are mapped while social and ecological systems are not.
Figure 2.9. Taxonomy Tree of Discipline of Technology (DeVore, 1964)

The taxonomy below effectively depicts an automotive system, or specifically the options in an electric propulsion system for an automobile. Like other maps, taxonomies communicate order and relationships. Tree formats are hierarchical arrangements or classifications of concepts (Fig. 2.10). Systems can be divided and subdivided into any number of components. Like mind maps and schematics, taxonomy trees are advance organizers for students. They effectively organize and simplify knowledge. When we organize data or information we create knowledge. While essential to teachers, it is extremely important that students develop and utilize these mapping techniques as well.
Timelines, Tables, Charts and Graphs

While images are extremely effective, propositional knowledge is also quite effective in timeline, table, chart or graph form. Timelines organize knowledge chronologically by serializing dates, names, places and events (Fig. 2.11). Timelines are a key to organizing historical knowledge for your students. At one time or another, nearly every technology that teachers teach will have to be placed in a historical context. Timelines are also quite accessible to students, who can create their own sequences of events related to one technology or another.

Take the issue of CFCs and the depletion of the ozone layer of the Earth. We rarely hear about this issue anymore, but the ozone "hole" keeps growing larger, and cases of skin cancer across the world continue to increase. The links between the two may not be as causal as some claim, but the reality of a more dangerous sun is undeniable for those living in the southern hemisphere. How do we teach about this in a technology course? How can we organize what we know about the facts? We can begin by looking historically at the issue. Willis Carrier developed an air-conditioning system in 1902. But his system was dependent on cold air drawn from ice and cold water. It was not until twenty-five years later that Thomas Midgely invented a coolant and DuPont and General Motors eventually introduced the coolant called Freon. By the mid 1980s, when the ozone hole was recognized, the US was producing more than their share of CFC's in the form of 2.7 million new residential air conditioners, 5.8 million refrigerators, and 1.1 million freezers per year. Rolling off the assembly lines were 7.8 million cars and 3.4 million trucks and buses. But all of this is better organized in graphic forms (Fig. 2.11, Table 2.1).
Figure 2.11. Timeline of CFC Events

- Thomas Midgely invents a non-toxic, non-flammable coolant - 1928 (Fridgesaire Division of General Motors)
- DuPont & General Motors introduce Freon (End of ice-box age) - 1931
- CFC's used as propellants to fight malaria - WW II
- CFC's find use in the plastics industry as blowing agents - 1950's
  - The potential of CFC cooling power is finally realized - AC takes off in a big way - 1950's
  - Joseph Farman (British Antarctic Survey) begins monitoring ozone levels - 1957
- Rowland-Molina study links CFC's to ozone layer depletion and predicts that 99% of all CFC's end up in stratosphere
  - CFC lifespan = 100 yrs+ - June, 1974
- DuPont pledges to cease CFC production if scientific evidence finds CFC's to be harmful - June, 1974
  - DuPont issues statement in an effort to refute CFC-Ozone links - March 15, 1975
- CFC-113 is introduced as cleaning agent for electronic circuitry - 1976
  - Non-essential use of aerosols is banned worldwide - 1978
- Alliance for Responsible CFC Policy is formed - 1981
- Dr. Teramura, working at the University of Maryland, begins research on UV-B and its effects on Soy Bean yield - 1984
- British Scientists report Antarctic ozone hole - May, 1985
- Vienna Convention (UN) "Protection of the ozone layer" - 1985
- Airborne Antarctic Ozone Expedition uses NASA "ER-2" (Spy plane/Flying Laboratory) to collect and analyze data at 67,000 ft. 2 months of 18 hr days - August, 1986
- 100th Congress enacts a bill to reduce ozone depletion - Feb 19, 1986
  - Congress also enacts legislation to improve efficiency of home appliances - 1986
- Ozone Trends Panel begins Study - Oct, 1987
- US EPA "Environmental Impact Analysis" - Dec, 87
  - Berkeley, Ca. proposes ban on all foam containers Jan, 1988
- US Senate votes to ratify Montreal Protocol March 14, 1988
- DuPont calls for total phaseout by 2000 March 24, 1988
  - Phaseout agreement by foam container industry April 14, 1988
### Table 2.1. Table of Production of CFCs

**Fully Halogenated Alkanes**  
**U.S. Economic scope (Annual)**

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>INTERACTION WITH SOCIETY</th>
<th>VALUE OF PRODUCTS /SERVICES</th>
<th>DIRECT CFC RELATED IND. EMPLOYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>REFRIGERATION</td>
<td>85 million hsehld 'Fridges 28 million hsehld freezers 178,000 Fridge Trucks 27,000 Rail Cars 160,000 Food Stores 39,000 Supermarkets 250,000 Restaurants</td>
<td>$6 BILLION</td>
<td>52,000</td>
</tr>
<tr>
<td>AIR-CONDITIONING</td>
<td>40 Million homes/ess all offices, com., public bidg</td>
<td>$10.9 BILLION</td>
<td>125,000</td>
</tr>
<tr>
<td>MOBILE A-C</td>
<td>60-70 Million autos &amp; trucks</td>
<td>$2 Billion</td>
<td>25,000</td>
</tr>
<tr>
<td>A-C &amp; REFRIG SERVICING</td>
<td>All existing Fridges &amp; A-C's</td>
<td>$5.5Billion</td>
<td>472,000</td>
</tr>
<tr>
<td>PLASTIC FOAM</td>
<td>Insul Foam for homes, fridges, food trays/pack. cushion foams</td>
<td>$2 Billion</td>
<td>40,000</td>
</tr>
<tr>
<td>SOLVENTS</td>
<td>Microelec circuitry, Spacecraft and computers</td>
<td>Bills</td>
<td>?</td>
</tr>
<tr>
<td>FOOD FREEZANTS</td>
<td>Frozen Fish, shrimp, fruit &amp; veges</td>
<td>$0.4 Billion</td>
<td>&lt;1000</td>
</tr>
<tr>
<td>STERILANTS</td>
<td>Medical items, catheters, respir units, supplies, drugs</td>
<td>$0.1 Billion Steril. Equip.</td>
<td>&lt;1000</td>
</tr>
<tr>
<td>FIRE PROTECTION</td>
<td>Extinguishers</td>
<td>Millions</td>
<td>?</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>$26.9 Billion</td>
<td>375,000</td>
</tr>
</tbody>
</table>

Tables organize a range of data that can be cultural (number of hours of television viewed in one year), social (number of females employed in high tech industries) or technical (measurements in a wind tunnel) (Table 2.1). The visual representation of data with tables, charts and graphs is extremely helpful to communicate propositional knowledge in technology. Scientific visualization is the concept that refers to the development of techniques to present scientific and technical information. With the power of digital graphics, the graphic presentation of information is limited only to our imagination. During the 1990s, there was a revolution in capabilities to animate and present information in three-dimensional models. Modeling has completely transformed capabilities for organizing and representing technical information for architects, astronomers, designers, geologists and geographers, for example.

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Charts and graphs are essential for demonstrating ratios and relationships ranges of data. At a glance, they help us to draw inferences. They help us to establish facts from data and generalizations from facts. Pie charts provide visual portrayals of percentages or ratios. The two pie charts below indicate the changes in labor force distributions in the US at two different points in history (Fig. 2.12). The increase in the manufacturing sector was reflected in the marketing and popularity of home conveniences, such as air conditioners produced by Carrier and York.

**Figure 2.12. Pie Charts of the US Labor Force, 1920, 1984**

There are generally two types of graphs: Bar and Line. Somewhat like pie charts, bar graphs allow us to compare discontinuous categories of data. For example, the bar graph below allows us to compare passenger carriers in the US at five different points in time (Fig. 2.13). Line graphs allow us to compare continuous data over time (Fig. 2.14). They are extremely effective for plotting changes over time. Graphs help provide a visual record of technological data. For example, at one glance we could infer from plotted measurements in a wind tunnel at different speeds, the volume of spam received over a month or the rise and fall of telephone and telegraph messages over a century (Fig. 2.13). For some reason, students learn to associate graphs with math and science and fail to associate graphing with design and technology.
Figure 2.13. Bar Graph of US Passenger Carriers, 1939-1978

Figure 2.14. Line Graph of Communication Messages, 1880-1980
Technology teachers should feel comfortable using a variety of techniques for organizing propositional knowledge. There are varieties of mind map styles for organizing propositional knowledge and for communicating. Hub designs, fishbone designs, network designs, trees and webs employ different ways of relating concepts. Mind maps and schematics are effective for conveying propositional knowledge but quite ineffective for dealing with procedural knowledge. Practice communicating with schematics that are sketched, drafted or scanned. Make liberal use of diagrams, timelines, tables, charts and graphs to communicate with your students. Venture into the world of scientific and technical visualization to animate knowledge and make it clear and visible. The images that you create with these techniques will serve as advance organizers for your students.

**Scientific and Technical Visualization**

Scientific and technical visualization (Sci Vis) is a field that became extremely popular during the 1980s and 1990s due to the availability of powerful hardware systems and accessible imaging software. Books published by Tufte, such as *The Visual Display of Quantitative Information* and *Envisioning Information* laid the theoretical foundation for this popularity. Digital animation and simulations transformed the way that scientific and technical information could be displayed or presented. Modeling software, such as AutoCAD, Pro-Engineer, Pro-Desktop and TrueSpace provided powerful tools for manipulating vast amounts of data for design and analysis. Animation software such as 3D Studio offered complex techniques for giving motion to static data and for simulating live action. Scientific and technical visualization were transformed. One of the most effective visualization databases was McCauley’s *The Way Things Work*, which demonstrated how the new techniques could be used to animate the workings of a wide range of technologies. Teachers who once struggled to demonstrate the internal workings of combustion or electrical power generation turned toward the new techniques of Sci Vis to clarify what they were teaching. Technology teachers finally had the tools and techniques to represent the 3D world that they once struggled to represent in 2D. In the late 1990s, Sci Vis became a course option in the digital media design curriculum (Clark and Wiebe, 2001; Wiebe, 1992; Wiebe and Clark, 1998). It is essential that technology teachers have the skills to draw on these new techniques for organizing knowledge and for assisting students to animate, model and simulate. Scientific and technical visualization reduce visual forms to four primary attributes:

- **Form** (metric or stereometric form; shape of line, surface, 3D solid)
- **Surface characteristics** (color, pattern, texture, thickness)
- **Spatial relationships** (relationships of forms and surfaces in space)
- **Temporal qualities** (movement via frames and vectors; static and dynamic qualities)

Sci Vis requires that we understand how to represent and manipulate these four
attributes via hand rendered drawing and photography or computer software. Representation of the world of science and technology is basically either concept or data driven. Concept driven representation deals with scientific or technical concepts such as internal combustion, nanotechnological movement or hydraulic flow. Data driven representation deals with data such as pollutants and particulates in urban centers or PCB build-up in small lakes. Eric Wiebe, pioneer in introducing Sci Vis to technology studies, has inspired teachers to create learning objects and databases or images for teaching biotechnology, medical imaging, molecular modeling and robotics, among other fields.

**Propositional Knowledge in Technology Studies: Information Sheets**

Typically, mind maps and schematics are used in conjunction with information sheets as handouts. Information sheets provide a background and context for design and technological practices. They reinforce the procedural knowledge of the same practices and are essential to developing technological literacy in students. Generally, each procedure sheet ought to be accompanied by an information sheet. Information sheets may provide a geographic or historical background, may describe the mathematical and scientific principles underlying a technology, or may present ecological issues related to a practice. They may expand on the technological concept at hand or provide a description of the operations of an application, tool or machine. There is a wide range of possibilities for information sheets.

The propositional knowledge of an information sheet must be accurate and factual. This requires that a fair amount of research and synthesis be completed prior to the creation of an information sheet. Certainly, the information and images provided can be paraphrased and scanned from sources. In most cases, the information retrieved has to be condensed or rewritten to be appropriate for the audience of students. The information sheet that follows is a complement to the micrometer lesson plan provided in the first chapter. It would be used as a handout and as a guide for the teacher in a demonstration that deals with the social issues, or sociotechnical knowledge, of the micrometer. This particular information sheet is written at the level of high school seniors and postsecondary students.

This sheet is a good example of a bad example. While the information is accurate, there are some obvious problems with the presentation. Given what we know about graphic design, is this an effective handout? What can be done to improve this? What determines the quality of an information sheet? The key is to develop a format that is consistent and responds to principles of graphic design.
Information Sheet
Micrometers and Production Measurement

Interchangeable manufacturing, by means of which parts can be made in widely separated localities and then brought together for assembly, where the parts will all fit together properly, is an essential element of mass production. Without interchangeable manufacturing, modern industry could not exist, and without effective size control by designer and producer, interchangeable manufacturing could not be achieved. Mass production was made possible through the development of precision instruments, among other changes during the 19th century. During industrial revolutions in England and the US in the 18th century, workers who could machine to high levels of precision were in high demand. Yet by the late 1900s, for many machinists, the skills necessary for precision measurement were automated—machine tools had begun to be designed that had the capability to work to precise dimensions. In Henry Ford’s case, with his assembly line for mass-producing Model T “Ford” cars, factory workers did little more than assemble parts. For Ford and his managers, a deskilled worker on an assembly line had little power to agitate for economic justice. For Ford, his worker was getting more than the worker deserved.

Micrometers
A community of machinists working at the Harpers Ferry Armory achieved interchangeability around 1831. The armory was used in the production of rifles for the US Army and for private use, and had been a site of forms of automation for a few decades. John Hall has been given credit for designing and managing the first successful trials of interchangeability. Machinists through the use of gauges, gauge blocks and plugs—"go and no-go plugs", controlled precision machining at the armory. This system had remained common practice until the 1870s. During the late 1860s however, sheet metal manufacturers in New England had become dissatisfied with inconsistencies in the metal they produced. They had been using sets of fixed sheet metal gauges, but no two gauges were alike and were accurate to only+/- .01 inch. Around 1867, Brown and Sharpe, precision gauge manufacturers, were asked by a sheet metal producer to design and produce a gauge based on the screw principle. Brown and Sharpe had visited a Paris exhibition in 1867 and saw an instrument displayed called a screw caliper, or Systeme Palmer, developed by Jean Laurent Palmer. They returned to New England, designed and manufactured their own version of the screw caliper, and marketed it as a "Pocket Sheet Metal Gage" until 1877, when they renamed it the micrometer caliper. With the micrometer, machinists could now work to precision within .001 of an inch.

Tolerances and Fits
The critical nature of interchangeability is such that the proper functioning and mating of parts or surfaces and the cost of producing and assembling of parts are dependent on precision. Dimensions are used primarily on detail design drawings for the guidance of workers who are responsible for the manufacture of the component parts of various mechanisms or products. However, in production, there had been a realization that exact sizes are not needed. Only varying degrees of accuracy according to functional requirements were necessary. It is impossible to make anything to exact size. So what was needed was a means of specifying dimensions with respect to the required degrees of accuracy. Prior to changes in manufacturing at Harpers Ferry, mating parts were filed to fit together. With changes in precision machine tools had come a system of tolerances and fits. Parts could then be produced to fall within a range of precise sizes, and graded as "good" or "no good." Varying degrees of accuracy are acceptable for parts that fit together.

New Terms:
Tolerance- Limits-
Bilateral tolerance- Basic size-
Unilateral tolerance-Fit- Mean size-
Allowance- Nominal size-

Maximum dimension-
Minimum dimension-

Maximum material condition (MMC)-
Least material condition (LMC)-

References:
**Procedural Knowledge in Technology Studies: Procedure Sheets**

As we defined it earlier, procedural knowledge is basically know-how. Some people claim that know-how is the essence of design and technology without acknowledging that know-how by itself is inadequate to design, make, maintain and regulate technological activities and things. We are not born with an innate procedural knowledge of how to safely play and work in the world. We develop procedural knowledge through education and observation. Once a teacher derives procedural knowledge through task analysis, the knowledge has to be organized.

Recall that procedural knowledge is defined by its procedural order: Step 1, Step 2, Step 3, etc. If the order is mixed, the procedure changes. With technical procedures that involve chemicals, heat or machines the displacement of one step with another could result in injury. Most mind maps and diagrams blur procedural order and allow for various interpretations of procedures. Of course, with procedural knowledge, various interpretations are *not* what we want. The only diagram that is effective for conveying procedural knowledge is the flow chart (Fig. 2.15).

![Flow Chart of Flashlight Test System](image)

*Figure 2.15. Flow Chart of Flashlight Test System*
In technology studies, we typically demonstrate how individual procedures ought to be completed. We show the students how to safely and effectively complete social and technological procedures. As we realized in the first chapter, teachers dedicate a large amount of time to organizing the steps of a demonstration. We do this for two reasons: 1) to organize ourselves for communication and instruction, and 2) to organize the knowledge that we are sharing. Both propositional and procedural knowledge must be organized for and with the students.

Along with flow charts, the most common form for conveying procedural knowledge is the procedure sheet. Information and procedure sheets are complements. One deals with propositional knowledge and the other with procedural knowledge (see definitions below). The organization of knowledge in the two formats is much different. Procedure sheets (and safety sheets) present directions in step-by-step format. They empower students with clear, concise directions for safely and successfully completing a technological procedure. Procedure sheets are invaluable in design and technology and challenge teachers to clarify instructions and reduce them to procedural directions.

**Fundamental Definitions: Handouts (Graphic and Textual Forms) for Teaching**

**Activity Sheet**— This form explains the reason and procedures necessary to complete an activity that is not a design challenge or project.

**Design or Project Brief**— This form provides the information necessary, such as problem, constraints, and assessment criteria, for completing a design challenge or project.

**Exercise Sheet**— This form presents provisions for development of skill and knowledge regarding academic or technical content.

**Information Sheet**— This form provides knowledge regarding the background or context—socio-political, ethical-personal or ecological— of lab/shop practice or of some apparatus, material, tool, machine or process. (Contextual or declarative knowledge)

**Procedure Sheet**— This form explains, in detail, the knowledge and technique necessary for lab/shop practice or use of an apparatus, material, tool, machine or process. (Procedural Knowledge)

**Safety Sheet**— This form provides necessary knowledge regarding safe practices in shops and labs, and in use of apparatus, materials, tools, machines and processes.

Procedure sheets, indeed procedures, need not be fully invented or contrived by teachers. Teachers ought to feel free to borrow and quote procedures from reliable sources. One major reason why teachers must be cautious with procedural knowledge is **liability**. When a teacher creates a procedure sheet, s/he is responsible for the information within. However, if the
information is original (i.e., the teacher’s) then the teacher can be held liable. Consider a procedure for completing an operation on the table saw, represented in the next two boxes.

<table>
<thead>
<tr>
<th>Procedure Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table Saw: Ripping</strong></td>
</tr>
</tbody>
</table>

Ripping is the act of cutting your work-piece with the grain of the wood - or “cutting to width”

1. **Be ready to work safely!**
2. Measure stock. *If stock is 12 inches (30 cm) or longer you can use the table saw to rip.* If stock is 4 inches (10 cm) or wider a Push Stick is not necessary. Otherwise, prepare to use a Push Stick.
3. **Check to make sure machine is off**
4. Adjust the distance between your blade and the **Rip Fence** face to match the desired stock width. Be sure to measure this distance from a blade tooth that is “set” toward the Rip Fence.
5. Place the dimension of stock to be removed to **left of blade**
6. Adjust and lock fence in place and measure distance again. Readjust if necessary.
7. **Position and keep body to the left of blade until finished**
8. Turn machine on—**Concentrate on procedure, work-piece and blade.**
9. **Begin your cut** with one hand gripping your stock at the back edge in preparation for pushing it through the cut. If you’re ripping short pieces of stock, position your other hand at the side of the stock (forward of the in-feed side of the blade) and pressing in on your stock to hold it firmly against the Fence. This “pressing-in” hand should not be near the rotating blade or pressing the stock against the blade after the cut has been made. If pressure is applied at a point where it closes the freshly cut saw kerf on the blade, a dangerous kickback will occur.
10. If you’re ripping longer pieces of stock where you need both of your hands to safely hold and guide the stock forward through the cut (and the width of your board and the set-up permits), use a Feather-board (**Stop: See teacher for this!**)
11. When ripping narrow pieces of stock (10 cm or less) use a **Push Block** or **Push Stick** to move the stock through the cut once your “pushing” hand begins to approach the moving blade.
12. **Carefully push stock** through blade at even speed and once through let stock fall on floor or support table.
13. Do not touch scrap to left of blade
14. Turn machine off
15. When blade stops spinning, lower it so that it is below the table surface
16. If you’re ripping long pieces of stock, be sure you have plenty of work-piece support, both before and after you make your cut (**Stop: See teacher for this**)
Procedure Sheet  
Table Saw: Ripping

Ripping is the act of cutting your work-piece with the grain of the wood- or "cutting to width." When making rip cuts, use a ripping or combination blade and ALWAYS guide your stock against a Rip Fence. Start by adjusting the distance between your blade and the Rip Fence face to match the desired stock width. Be sure to measure this distance from a blade tooth that is "set" toward the Rip Fence face. Unplug your saw before taking this measurement. If your Rip Fence is properly aligned, you need only measure this distance at one point. However, if you’re not confident of this alignment—or you’re working on a project where the width of your finished board is critical to within 1/32" or so, it’s a good idea to measure this distance at two points. Here’s how. Find a tooth that’s set toward the Rip Fence. Rotate this tooth forward until it’s just above the saw table surface near the in-feed edge of the table. Measure the distance to the Fence face. Rotate this same tooth backwards until it’s in the same relative position near the off-feed edge of the table. Measure the distance to the Fence face. If these two distances aren’t equal, your Fence is not properly aligned and an adjustment needs to be made.

Begin your cut with one hand gripping your stock at the back edge in preparation for pushing it through the cut. If you’re ripping short pieces of stock, position your other hand at the side of the stock (forward of the in-feed side of the blade) and pressing in on your stock to hold it firmly against the Fence. This “pressing-in” hand should not be near the rotating blade or pressing the stock against the blade after the cut has been made. If pressure is applied at a point where it closes the freshly cut saw kerf on the blade, a dangerous kickback will occur. If you’re ripping longer pieces of stock where you need both of your hands to safely hold and guide the stock forward through the cut (and the width of your board and the set-up permits), use a Feather-board to hold your stock in against the Fence during the cut. Again, keep the Feather-board forward of the blade so it isn’t pressing against the blade or closing the saw kerf after the cut has been made.

When the distance between your Rip Fence and the saw blade permits, use a Push Block or Push Stick to move the stock through the cut once your “pushing” hand begins to approach the moving blade. When this distance is 1-1/2” to 3”, use a Fence Straddler as a safety aid. If you’re ripping long pieces of stock, be sure you have plenty of work-piece support, both before and after you make your cut. A special Support Table will be an invaluable aid in these situations. It will extend your outboard support 32” on the off-feed end of the Worktable. For even more support, an adjustable Roller Support Stand is recommended.

From Shopsmith (http://www.woodshoptips.com/tips/082602/page5.htm)

Compare the two procedure sheets for the table saw. Which of the two would you feel most secure with? Why? What are the advantages of the first format over the second? If the teacher
fails to provide complete directions or inaccurate directions, and a student who follows these directions is injured, then the teacher can be held liable. Teachers can protect themselves by insuring that procedure sheets are accurate and derived from reliable sources. Procedural knowledge ought to be organized in step-by-step format. The next procedure sheet deals with a specific type of scanner. Note the detail necessary to clearly convey procedural knowledge.

**Procedure Sheet**

**How To Use the Umax Scanner:**

*Make sure the Scanner is plugged in (powered up)*

1. Launch Adobe Photo Deluxe (double click on icon at bottom of screen)
2. Pull down 'File' menu to 'Acquire' and over to 'VistaScan 2.4.3…'
3. In new pop-up window, click on 'Preview' (assuming you have already positioned the image to be scanned on the scanner bed upper left corner) (Tip: it is best to leave settings at their defaults)
4. After preview scan, crop scanned image by pulling dotted-line window around desired image
5. Click on 'Scan'
6. After scan, if happy with image, pull down 'File' menu to 'Export' and over to 'File Formats'
7. In new pop-up window, rename image file (eg, image1.jpg or image1.gif)
8. Pull down 'Format' menu in pop-up window to JPEG for scanned photos or to GIF for scanned line art, figures, etc.
9. Save file in 'Student Temp Files' folder or on floppy or zip disk
10. Click on save (the file is now written and exported to the destination folder as a JPEG file)
11. Close image window by clicking in upper left corner: DO NOT SAVE!
12. Start over at step #2 if scanning a second image
13. To edit image, it is recommended that you use Graphic Converter (for basic editing) or Corel Photo Paint or Adobe Photoshop (for advanced editing)

Because you clearly demonstrate a procedure and develop a good, clear procedure sheet to supplement the lesson does not mean that students will automatically learn the procedure. As we will discuss in the next two chapters, students learn differently and have different preferences for learning. Some will retain a large portion of the procedure from the demonstration. Some will rely on the procedure sheet. Others will need to physically walk through the procedure and practice—they have to embody the procedure. Still others will rely on visual cues, such as color, to organize procedural knowledge. You may have to color code procedural steps: the initial steps green, the middle steps blue and the final steps red. Recall that the movement through procedural knowledge...
ought to be from directions, to rules of thumb (algorithms) to strategies. Our goal is to not merely assist students in learning a particular procedure, but to assist the in developing rules of thumb and strategies for internalizing any procedural knowledge in the future. The goal is to help them to learn how to learn.

Projection & Reflective Practice

We began this chapter by reviewing the new views of intelligence and their relation to knowledge. We defined procedural and propositional knowledge and explained how knowledge is articulated and integrated into experience. We also drew distinctions between technical and sociotechnical knowledge. A range of effective techniques for organizing knowledge for instruction was presented. These techniques serve as advance organizers for students. Mind maps, schematics, taxonomies, timelines, graphs, charts, information sheets, flow charts and procedure sheets are invaluable techniques for creating advance organizers. The field of scientific and technical visualization has transformed the way that technology teachers organize knowledge and present ecological, social and technical processes. We described a range of cognitive skills that are employed in design and technological processes. In the next chapter we address action and emotion and their interrelations with cognition.

1. **Procedure and Information Sheets:** Prepare a set of procedure and information sheets (digital and hard copy) for each of two different apparatuses, devices, machines, materials, processes or tools. For example, if you choose the scanner you will prepare procedure and information sheets for this device. Procedure + information sheet = one set. The second technology that you choose will also require a set of procedure and information sheets. Choose an apparatus, tool, material, machine or process that you know you will be teaching. Each procedure and information sheet ought to integrate images with text. Use mind maps and schematics for propositional knowledge and flow charts for procedural knowledge. Each sheet ought to be accurate in terms of information and professional looking. The trick is to develop a format that you can use for each procedure and information sheet. Once you have established a format for each type of handout, successive handouts will be easier to create. Your students will benefit from the consistency. Keep the length of each sheet to one to two pages. Pay attention quality of content, graphic design, organization of knowledge and media sophistication.

2. **Advance Organizers:** Create two **Mind Maps** and two **Schematics** that articulate propositional knowledge for a design or technological concept, process or system. These will be advance organizers for your students. For example, how would we describe the internet? How would we convey the process of metal smelting? How can we present the major components of a computer system? Either incorporate these mind maps into your information sheets or create overheads that you will use in a demonstration. Get in the habit of using mind maps to articulate knowledge to your students!

3. **Scientific and Technical Visualization:** Create a digital 3D simulation of some ecological, social, technical or sociotechnical process. Creatively model some process that has not been previously simulated or re-model an existing simulation. Like mind maps and schematics, simulations serve as advance organizers.