

THE EFFECTIVENESS OF THE ADDITION OF ILLUSTRATION TO A DESIGN
UNIT PRESENTED TO SIXTH GRADE STUDENTS AT SAMUEL MORSE MIDDLE
SCHOOL IN MILWAUKEE, WISCONSIN DURING THE 2003/2004 SCHOOL YEAR

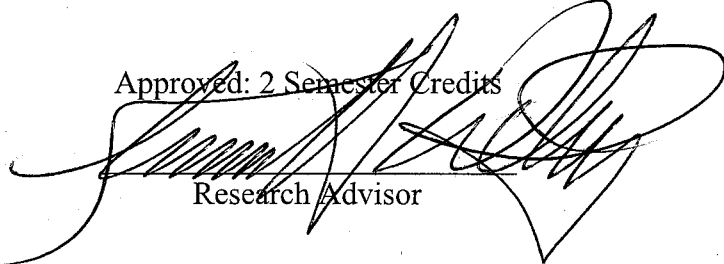
by

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ABSTRACT

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The Effectiveness of the Addition of Illustration To a Design Unit Presented to Sixth-grade Students at Samuel Morse Middle School in Milwaukee, Wisconsin During the 2003/2004 School Year.

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This quasi-experimental research study measured student performance through the addition of rich, highly graphic illustration to a design unit presented to two classes of sixth-grade students at Samuel Morse Middle School in Milwaukee, Wisconsin during the 2003/2004 school year. Students completed identical worksheet activities, after completion of content material presented to the two groups in a textual format, and an illustrated version of the textual format.

Quantitative data collected on student worksheet performance included: discrimination between problems and solutions, definition of an authentic technological problem, discrimination between different types of information, brainstorming, rough sketching, refined sketching, and attentiveness to design criteria.

Individual student composite scores were analyzed using the two-sample with equal variance t-test formula. It was concluded that the addition of rich, highly graphic illustration to the design unit resulted in no significant difference in student performance.

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Chapter 1

Introduction

Background

There have been several studies during the past century regarding learning styles, cognition, the use of different media in education, teaching strategies, curricula design, educational theory, and levels of learning in different domains. The large quantity of educational studies conducted over the years have contributed to the body of knowledge that has shaped current principles of learning and teaching. Students learn in the cognitive domain, the affective domain and the psychomotor domain. Students learn at the general knowledge, working knowledge or qualified knowledge level or a combination of the above (Bott, 1996). Learning depends on the instructional material being presented to the student, the method it is presented, the quality of the presentation and the engagement of the student to the instructional material being presented.

Several studies have been conducted indicating relationships and effects of multi-media used in the educational process, and when visual representation of information was unavailable, conclusions have been drawn that people will develop mental images to represent textual information being read. One such study by Jehng, Tung, and Chang, (1999) examined the use of schematic-based pictorial notations in the teaching of complex computer programming techniques. The researchers cited multiple examples of mathematicians using diagrams to solve geometric problems, and scientists using diagrams to analyze and interpret data. Jehng, Tung, and Chang's study measured

whether students should be presented with complex computer programming curricula in textual form only or a combination of textual and visual forms.

In a related educational study regarding the format of information presented in the classroom, Maloch (2002) stated that traditionally, education is delivered in the classroom through a series of conversational communication between student and instructor, while Heba (1994) stated that in certain educational areas such as writing instruction courses, printed textual material is the dominant delivery method of instruction.

Heba continued in his study of the communication process by stating that, although people believe in the written word as being more accurate, and often more “official” (p. 3), inter-media communication can enhance the educational communication process. He cited Bates (1980), who indicated that increased learning takes place in an environment where more senses are stimulated, leading to a greater receptivity of knowledge and greater retention. Bates cautioned, however, that while a “gestalt approach to visual design” (p. 399) can enhance learning, from a semiotic perspective, inter-media rhetoric must be done correctly to be effective.

Tomaseviae-Daneevaie’s (1999) study on the ability of people to speak “visual language” discussed the intuitive abilities of people to communicate without formal literal conventions. Lowe (2000) agreed with this perspective to a point, stating that while visual language is used in near universal settings under certain circumstances, including simple symbolic signage used in international airports, he asserted that abstract scientific and technical symbolism requires more in-depth understanding of the graphical conventions used to communicate without the use of text. Skill is required to decode

graphic representation of technical information that goes well beyond low-level intuitive visual language.

Studies have shown that the use of visual aids as educational curriculum in conjunction with conversational and textual delivery of information have a direct positive impact on learning. Recent advances in communication technology have given rise to the use of realistic computer simulation and data visualization. One example of the use of sophisticated non-textual educational media having a positive impact on learning was reported by Mahendren, Mahen, Young, and Joseph (1998). In this case, civil engineering students found visual simulations of load limit failures useful in the understanding of complex stress and load bearing formulae used in calculating structural limits of steel columns used in construction. The simulated buckling of steel columns helped the students visualize the mathematical calculations and relationships of the different formulae used in calculating the specifications to build the steel columns. As a result, the time needed for the professor to explain the concepts was reduced.

Other forms of visualization are helpful to students. According to Topp (1996), when the learning objective is more consistent shooting of a basketball, some physical education teachers encourage students to concentrate on the rim and visualize the ball going through as they shoot rather than teaching students to keep their eyes on the basketball as they release their shot.

Spatial visualization techniques are important to students for a number of reasons, including the ability to mentally manipulate information (Jacobson & Lehrer, 2000) and to be able to look at information represented in two dimensions and convert the information to three dimensions in their minds (Kwon, 2001). Kwom cautioned,

however, that visual information in the early forms of virtual reality was somewhat unsophisticated and at times resulted in passive experiences for the user.

Other areas of research related to the communication of technical information in educational settings include an analysis of semiotic theory and document design by Ding (2000), and vision, visualization, and representation studied by Duval (1999). The understanding of charts and graphs and the cognitive processes involved were studied by Kosslyn and Stephen (1983), and the effect of visualization and the use of job aids in the facilitation of cognitive development was researched by Spaulding and Dwyer (1999).

Recent research into the understanding of how individual learners organize data, formulate cognitive scheme and retrieve knowledge, and improved teaching strategies making use of graphic representation of information used in educational settings include work by Lowe (2001) and Van Horn (2003). Discussed is the need for high-quality teaching strategies for the delivery of technical education in multimedia formats, including textual and graphic channels.

The Bachelor of Science degree and Master of Science degree in Technology Education at the University of Wisconsin-Stout prepare secondary Technology Education teachers. Students in the Technology Education program are required to successfully complete a pre-clinical experience to satisfy conditions of the Wisconsin 220 teacher's license. The pre-clinical experience is a form of observatory fieldwork for prospective secondary Technology Education teachers. The class is divided into five modules, or units. Modules one through three involve observation of students in a secondary school classroom. Small written assignments are turned in to the university professor at the completion of each observational module. Some interaction between the university

student and the secondary school students is encouraged as part of the observation process.

Module five of the pre-clinical experience is optional, and involves the university student taking steps to identify, trouble-shoot and solve a minor problem with the operation of the class being observed, with the help of the cooperating teacher.

The written behavioral objective for module four of the pre-clinical experience reads,

“Given a topic by their cooperating teacher, students will be able to develop a poster that describes a laboratory process and meets the standards provided to the cooperating teachers satisfaction” (Anderson, 2002, n.p.).

The cooperating teachers use the following evaluation criteria for the poster;

The poster:

1. is well constructed and all the graphic elements are physically secured to the board.
2. conveys its message quickly and clearly.
3. is attractive and holds the viewer's attention.
4. used proper spelling and written communication skills.
5. features directions that are technically accurate.
6. is visually legible from a distance.
7. is attentive to lettered neatness and quality.
8. can be easily displayed in the predetermined location. (Anderson, 2002, n.p.)

The assignment of producing the poster, displaying the poster and observing student reactions to the poster are detailed on approximately two typewritten pages of

information, with a one page rubric (Appendix A) and is graded on a three-point “Outstanding”, “Satisfactory”, or “Unsatisfactory” scale (Anderson, 2002, n.p.).

In addition to producing posters as a requirement to successful completion of the pre-clinical observation, Technology Education students at the University of Wisconsin-Stout produce units of instruction and worksheet activities throughout their program of instruction.

While extensive research regarding the communication of technical information using graphic formats has been conducted in the areas of mathematics, engineering, and computer programming education, recent contributions regarding this subject in the area of secondary Technology Education have been rare.

Statement of the Problem

Students enrolled in the Technology Education program at the University of Wisconsin-Stout produce, distribute, and display graphical representations of technical content material. The effectiveness of an illustrated artifact in meeting educational objectives of the secondary school students has not recently been analyzed. This study will analyze the effectiveness of the illustration of a design unit.

Purpose of the Study

The purpose of this study is to analyze the effectiveness of the illustration of a design unit by a student enrolled in the Technology Education program at the University of Wisconsin-Stout.

Research Questions

The following research questions will be addressed:

1. Do secondary students engage the illustrated design unit?

2. Do secondary students understand the illustrated design unit to be a learning tool?
3. Do secondary students meet the educational objective of the illustrated design unit by reading it?
4. Do secondary students require further instruction to meet the educational objective in addition reading the illustrated design unit in a classroom setting?

Significance of the Study

This study is significant for the following reasons:

1. Secondary students benefit through improved delivery methods of technical curricula.
2. Technology Education Students at the University of Wisconsin-Stout benefit through an expanded body of knowledge regarding the construction and implementation of the illustrated design unit as learning tools.
3. Technology Education instructors at the University of Wisconsin-Stout and cooperating teachers in the field benefit through measurable evidence regarding the effectiveness of the illustration of a design unit.
4. Other teacher education programs benefit through measurable evidence of the effectiveness of the illustration of a design unit.
5. Curriculum vendors benefit through measurable evidence of the effectiveness of the illustration of a design unit.

Assumptions

Secondary school students will be observed by the researcher during this study and their performance will be measured following their exposure to the research instrument. The following assumptions will be made in the collection the research data:

1. The students have a level of competence appropriate for their grade level.
2. The students have little prior knowledge to the content addressed in the design unit.

Limitations

Limitations to this study include:

1. The potential problem of secondary school students attempting to please the researcher. Student compliance rather than objective answers to worksheet activity questions can skew research data.
2. Research participants may be influenced by external factors prior to participation in the research study, influencing responses. Communication between the two groups of participating students, or other prior knowledge of the study, may influence research subject's behavior.
3. A limitation of this study may be the Hawthorne effect: the common phenomenon associated with human research where the research subjects behave differently than they otherwise would, simply because they are aware that they are being observed.
4. This research study will be limited by time, budget, and sample size. One class of sixth grade students will be available at Samuel Morse Middle School for the

control group, and one for the experimental group, during the timeframe allotted by the researcher.

Definition of Terms

1. Cognitive processes – the ways in which one thinks about information (Ormrod, 2000).
2. Gestalt – overall, widely encompassing perspective.
3. Rhetoric – influence through communication.
4. Schema – an organized body of knowledge about a specific topic (Ormrod, 2000).
5. Semantic – of or relating to meaning, especially meaning in language (American heritage college dictionary, 1997).
6. Semiotic – of or relating to semantics (American heritage college dictionary, 1997).
7. Wisconsin 220 license – teaching license required for Technology Education certification in Wisconsin.

Methodology

This quasi-experimental study used a cluster sampling method of data collection. The design unit depicted the steps involved in the clear identification of a technological problem, the establishment of: functional; production; market; and environmental criteria, the collection of information, and the development of design solutions. Students were provided with the design unit in the form of individual design portfolios. The textual version of the design unit was distributed to the control group (Appendix B). The illustrated version of the design unit (Appendix C) was distributed to the experimental

group. Working independently, the students completed the design unit in eight class periods. Data relating to student learning through the use of the design unit was collected and statistically analyzed.

The following chapter reviews and summarizes relationships and differences related to theoretical and practical aspects of multi-channel learning and other factors related to this research topic as reported in published literature.

Chapter 2

Literature Review

Introduction

This chapter will discuss the general principles of visual imagery, visual communication, and formats involved with textual and visual documentation. In addition, studies regarding cognitive processes associated with textual communication, visual communication, spatial visualization, memory, and technical information processing will be reviewed. The chapter will conclude with a report of findings from researchers in the areas of visual literacy, visualization and education, relationships between visual imagery, learning, the application of imagery to tasks, and the development of visual imagery communication abilities in students.

Rhetorical Situation

Audience, purpose, and context are three principles laid out by Kostelnick and Roberts (1998). Effective communication through the use of documents, either textual, visually illustrated or a combination of the two, depend upon the ability of the writer to focus on the needs and perspective of who will be reading the document, what the specific reason was for the document's creation, and the circumstances in which the document is read. These three elements make up the rhetorical situation. "The rhetorical situation drives the decisions you make during the entire communication process" (Kostelnick & Roberts, 1998, p. 5).

Visual Discourse Community

Kostelnick and Roberts (1998) described the visual discourse community as the audience engaging in various types of visual communication. Each particular visual

discourse community shares a common visual language. The visual discourse community can be of various sizes, ranging from a large culture, a medium size community, or a small organization.

In small visual discourse communities, limited numbers of people understand the conventions used. Few clues relating to the meanings of the symbols used in graphic representation are given by the writers of visual discourse, as the visual language used is readily understood by members of the visual discourse community. An example given in Kostelnick and Roberts (1998) discussion (Appendix D) showed a square drawn with solid lines containing a dotted-line square within it. Interpretations of this graphic representation could be kitchen table, with the dotted line representing the supporting base of the table to an architect or engineer reading a floor plan drawing.

Persons outside of the visual discourse community – those not trained in the use of this visual element and unaware of its meaning, do not recognize the representation as a table supported on a base. Other examples of visual elements accepted and understood by limited numbers of people, known as conventions, include scientific data displays, navigational maps, electrical circuit diagrams, and medical charts. “Like specialized jargon in writing, these conventions are too technical for lay readers” (Kostelnick & Roberts 1998, p. 36). The distinguishing factors between the visual discourse communities’ languages are the conventions used in the visual language.

Visual Images

Pierce (as cited in Bell, 1993) wrote that visual images are read in three ways: by resemblance; by logic; and by convention.

Examples of these three variations of visual images given in the article include the use of icons based on resemblance, useful where language barriers exist, such as in international airports. Icons of shuttle busses posted throughout the airport break down language barriers and are used by travelers regardless of verbal language.

Visual images based on logic include cause and effect style images, often used on warning signs, such as smoke and fire symbols, or an image of a machine operator with a hand caught on the rollers of a printing press. The operator can logically deduce that a hazard is present by the image of someone caught in the machine (Pierce, as cited in Bell 1993).

The third type of visual image categorized by Pierce (as cited in Bell 1993) were conventions.

Conventions

Visual conventions are the means of a sign system (Kepes, 1944). Visual conventions are learned and acquired, and depend on the audience accepting and understanding them (Morgan & Welton, 1992; Kostelnick & Roberts, 1998), are arbitrary and culturally bound (Hynka, 1989), and “Conventions are accepted ways of giving form to things” (Kostelnick & Roberts, 1998, p. 33). Spillman, Linder and Goforth (1983) referred to conventions as visual syntax used in visual language – accepted arrangements of visual elements used to express meaning.

Kostelnick and Roberts (1998) stated that visual communication conventions can be rigid or loosely held, and identification of relevant conventions is needed in the application of them to the rhetorical situation.

Examples of conventions accepted and readily understood by larger audiences are the triangular shaped sign signaling a warning to North American drivers, or a circle with a diagonal line through it signaling “no” or “not allowed”, as in “NO SMOKING” used by international audiences. These conventional symbols signify specific meanings, understood by people familiar with the convention (Kostelnick & Roberts, 1998).

Effective use of visual language conventions involves knowing when certain conventions are appropriate for a given purpose and context, when they are relevant for a situation, and when they are adaptable to a situation. Conventions are templates for visual communication documents, and must be used with reader’s knowledge of them in mind. Inappropriate use of visual conventions in relation to the audience’s acceptance and understanding of the conventions is readily noticeable (Kostelnick & Roberts 1998) and can hinder learning (Lowe, 1993).

Connotations

Morgan and Welton (1992) cautioned, however, that the use of familiar and readily accepted visual conventions to convey messages evoke connotations associated with the visual conventions. Appropriate connotations associated with the visual elements must enhance the visual message and not detract from it. Appendix E represents an example of a typeface connotation.

Bell (1993) wrote that the choice of typography affects the feeling, mood, and emphasis of the message by the connotations associated with the typeface selections, and that skill is required to effectively design visual messages. “The ability to understand one’s visual environment and interpret information of a visual nature are no longer passive skills that can be taken for granted” (Bell, 1993, p. 12).

Semiotics

While much of the literature related to the design, use, and comprehension of graphical and textual communication in the context of modern society, the debate actually goes back to at least 1641, when the oldest known reference to semiotics is found. Semiotics, the study of signs and their use in conveying meaning (Barnhart, as cited in Hynka, 1989) has recently been given attention by the educational profession, and Cunningham (as cited in Hynka, 1989) stated that “Education is a field in which semiotics has had relatively little impact” (p. 183).

Hynka (1989) and Bell (1993) described semiotics as the study of sign systems of all kinds, visual and otherwise, the coding of signs and the social functions of signs. Scholes (as cited in Hynka, 1989) stated that semiotics is a study of codes, the sociological inferences connected with the codes, and meanings assigned to these codes. Hynka (1989) quoted Eco, “Semiotics is concerned with everything that can be taken as a sign” (p. 184).

Perception

Perception requires thinking (Arnheim, cited in Kostelnick & Roberts, 1998). Readers search for focal points when looking over visual documents. They constantly search for a place to center their attention, and do not perceive everything in the document equally. Readers of visual documents proceed from the focal point and gather related information to clarify or quantify the context of the document.

Arnheim (cited in Kostelnick & Roberts, 1998) continued his description of the perception of information contained in visual documents by labeling it as visual thinking. A common breakdown in the engagement of these perceptions results from repetitious

pattern. Where no central focal point exists, the reader sees the entire pattern as the focal point rather than individual elements of the pattern. This disengagement of the individual conventional elements in the visual document results in the reader perceiving the document as a whole as being a monotonous pattern (Appendix F).

Selective Perception

Kostelnick and Roberts (1998) described selective perception as the filtering out of extraneous information, with readers of visual documents focusing vision to complete the task at hand. An example of selective perception given was a person entering a building, in a hurry to get to a meeting. The person looked for the door, then the door handle, opened the door, and proceeded to their meeting. The person did not take the time to notice the drapes, window frames or wall hangings in this situation. The person practiced selective perception. The authors continued by stating that in most perceptual situations, people process only the information needed to meet the person's situational goals as efficiently as possible.

Another goal-oriented type of selective perception used by people is scanning. Described by Morgan and Welton (1992) as rapidly surveying for details of most concern, scanning saves time by ignoring irrelevancies.

Kepes (1944) described the forces of visual attraction as being distinct visual traits, and that it is impossible to perceive visual units as isolated entities, but rather as relationships between the elemental components of visual material. The author illustrated this point with examples of optical illusions (Appendix G).

Kepes continued by stating that people reduce complex optical fields to basic inter-relationships, and illustrated this point with an example of camouflage (Appendix H).

These examples clearly show that individual elements of visual documentation do not stand alone, but exist as parts of the whole document. The reader's perception of the document's individual elements is characterized by the relationships between the elements.

Bertin (as cited in Kirsch, 1992) described graphics as a logical system with the goal of the reader being to understand a whole image. Bertin stated that this goal of understanding the whole image is possible only if readers fully understand component images within the graphic representation and the relationships the components have with the other components of the representation.

Gestalt Principles of Design

Kostelnick and Roberts (1998) defined the term "gestalt" as meaning "form". The gestalt form of a visual document impacts the reader's perception of the document as a whole. The whole form plays an essential role in understanding its parts. A reader's perception of the individual elements are affected by the layout of the document and the relationship these elements have with each other within the document. Two important principles the authors illustrated were figure-ground contrast and grouping.

The shaded square (Appendix I) dominates the visual depiction when standing alone. When the same shaded square is shown surrounded by a heavy arrow, the dominance of the shaded square diminishes, and in the third depiction, the same shaded box is all but lost among the background and clutter. In another example, figure-ground

contrast has the effect of separating one image from another, and distinguishing the placement of visual elements, making some look like they are in front, behind, or on top of other elements (Appendix J).

Morgan and Welton (1992) defined gestalt as “filling the gaps” (p. 67). The authors described gestalt as the perception of a collection of elements viewed as a whole, and not as individual elements. Using spatial proximity principles, readers fill in the gaps between visual elements, thus visually eliminating them. One example given by the authors was the use of half-tone screens in the printing industry, where pictures are made up of small, individual dots. Readers do not perceive dots, they see whole pictures.

Visual Noise

Morgan and Welton (1992) defined noise as “a distraction which disturbs the transmission of a message by intervening in the channel itself” (p. 15). Kostelnick and Roberts (1998) described visual noise as anything that impedes perceptual clarity of the message contained in the visual element or document.

The visual-ground contrast described by Kostelnick and Roberts (1998) can be degraded by visual noise (Appendix K). Visual noise appears in many forms, including selection of typeface, type size, type spacing, selection of background, and grouping.

Lack of attention to detail is a main cause of visual noise according to Morgan and Welton (1992), with dirty fingerprints on a drawing, crooked lines, faded color, and photos that lift up from a collage among examples given that distract the reader’s attention, resulting in interference of the intended visual message.

Visual Cohesion

Grouping tools used to manipulate selective perception and establish gestalt, whole-document patterns include grouping by shape, spatial nearness and division (Appendix L). These grouping techniques include the use of spatial nearness and division of pictures, icons and text, horizontal and linear alignment, likeness of form (shape), shading, bulleted lists, flow charts, and others, all serving the purpose of dividing documents into manageable units. Visual cohesion allows the reader to sort through the information contained in a document more efficiently (Kostelnick & Roberts, 1998).

Functional Documents

Flower, Hayes, and Swarts (1983) described functional documents as being different from other types of reading material. Expository prose, essays, novels, or reports, generally lay out a series of ideas to convey their information to readers. In contrast, functional documents, which include regulations, contracts, manuals, and procedures, have an additional goal. Functional documents not only convey information, but provide readers with specific instructions in order to perform a unique function.

Functional documents have a clear convention of outlining a specific sequence of instructions that need to be followed in order to achieve the objective of the writer and the reader of the document. The “scenario principle” researched Flower, Hayes, and Swarts (1983, p. 41) stated that “functional prose should be structured around a human agent performing actions in a particularized situation” (p. 42). The authors used the premise that the scenario principle is a radical departure from current logic and structure of Federal regulations and most contracts.

The scenario principle study analyzed the needs of readers and measured a significant amount of rephrasing by readers of functional documents in order to facilitate comprehension. The researchers studied protocols of contract and regulatory language and the associated cognitive processes involved that readers used to follow the instructions of the functional documents. Using tape-recorded transcripts the research subjects used to record their rephrasing of the functional documents, the researchers found that the subjects rephrased the textual information into a personalized scenario between 57% and 72% of the time.

Flower, Hayes, and Swarts (1983) concluded that the functional documents were so difficult for the subjects to read, they often had to rephrase the content message to themselves to understand the message, indicating that the documents were written with an emphasis on the writers' perspective rather than those of the persons reading the functional documents.

Emphasis and Technical Writing

Faigley and Witte (1983) wrote that although teachers of technical writing are concerned with the efficient transmission of information, little conclusive research has been conducted regarding features of efficient technical communication. The authors indicated that features including textual setting, sentence structure, and syntactic structures in scientific writing needed further study. Their study measured emphasis as a result of placement of the topic sentence in technical writing.

The study involved two sets of three sentences each containing identical technical content as determined by the number of technical details in each sentence. The structure of topical focus was varied by placement of technical details at either the first half or the

second half of the sentences. Research subjects were asked to review two sets of three sentences and record what they perceived to be the topics of the sentence clusters.

Although both sets of sentences contained identical technical details, the research subjects recorded different topics based on the placement of the technical details within the sentences. Faigley and Witte (1983) found that placement of technical details in the first half of sentences emphasized those technical details and significantly altered the reader's perception of the technical material's topic. See Appendix M for examples of technical writing sentence clusters used.

Levels of Effect

Findings by Faigley and Witte (1983) and Hucklin (1983) concluded that levels of effect and textual hierarchy, or the placement of information in a document, attributed to the importance readers assigned to information. Hucklin cited many studies indicating that readers tend to place greater importance on information placed higher in the hierarchy of documents. Labeling it the "leading-edge strategy" (p. 95), he stated that using textual features such as headings, subheadings, and topic sentences that lead off paragraphs focus the reader's attention and emphasized information.

Macrostructure Theory

Kieras used macrostructure theory developed by Kintsch and Dijk (as cited in Faigley & Witte, 1983), where readers reduced textual content into smaller topical ideas or expressions, or "macropropositions" (p. 61). The researchers found what they called the use of surface signals in passages of unfamiliar content. "Readers were much more likely to identify the main idea when it was verbalized in the initial sentence than when it

appeared in a non-initial sentence” (p. 61). The research indicated that the structure of the passage affected how readers comprehended and remembered it.

Readability Formulas

Seltzer (1983) wrote that “...readability is the efficiency with which a text can be comprehended by a reader, as measured by reading time, amount recalled, questions answered or some other quantifiable measure of a reader’s ability to process a text” (p. 73). The author contended that sentence length and word length were not the only factors that went into judging the readability of technical material. Seltzer went on to cite multiple authors who held that readability formulas were unreliable and invalid in evaluating technical material. The researcher stated that, contrary to convention, there existed no evidence that short sentences made technical content more comprehensible, yet many readability formulas are based on this factor.

The answer to the question of what made technical material more readable and comprehensible was not clear to Seltzer at the time of publication, however, he cited multiple authors claiming that certain word choices affected readability. Factors included the use of words that were familiar to the audience, were frequently used, and concrete as opposed to abstract words to successfully describe technical material.

Additional research conducted on the subject of “readability” of technical material and technical writing was conducted by Hucklin (1983). In his analysis of readability formulas, Hucklin stated that current readability formulas did not take into account the relevant factors involved with what made one piece of writing more readable than another.

Cognitive Psychology and Readability

The field of cognitive psychology has contributed considerably to the body of knowledge regarding the readability of technical documents by concentrating on the reading process. An operational definition described readability as “the extent that meaning can be easily and quickly comprehended for an intended purpose by an intended reader operating under normal conditions of alertness, motivation and time-pressure” (Hucklin, 1983, p. 91).

Schema Theory

Hucklin (1983) cited multiple studies in which readers having some prior knowledge of the technical content had more success in comprehending new, related technical material. The studies showed that the readers comprehended the new technical information more quickly, more thoroughly, and had better recall in more detail than the control subjects who had no prior knowledge of related technical material.

Hucklin (1983) and Ormrod (2000) cited Piaget’s work on schema theory regarding the organization and retrieval of information in people’s memory. The authors detailed Piaget’s research regarding when an author and a reader share a common schema, the author does not have to refer explicitly to all of the details of the subject matter, the reader is able to “fill in the slots....In this way a single word or phrase can actually call up an entire constellation of images in the reader’s mind” (Hucklin, 1983, p. 93). Schema-based inferring enriches imagery and increases coherence (Hucklin, 1983).

Working Memory

Headings, subheadings and topic sentences are especially important from a working memory standpoint (Hucklin, 1983; Ormrod, 2000), where the working memory consists of seven, plus or minus two, “chunks” of information, or schema, a person can actively process at any given time. For active processing of information to occur in the reader’s mind, schemata must be active and continually referred to before decay of working memory sets in and the new information leaves the working memory, to be filed away in long-term memory. The more inter-related the prior-knowledge is in a reader’s long-term memory, the larger the reader’s schemata. Studies by Hays-Roth and Thorndyke, Clark and Haviland, and others (as cited in Hucklin, 1983) showed that technical documents activated these inter-related long-term memory schemata in the reader’s mind by using “bridging inferences” (p. 98).

Specialists Communicating With Non-Specialists

Hucklin (1983) reported that technical specialists must use reader-based language to share schemata with the reader when composing documents. The use of common language - textual language as well as visual conventions - was used by writers to establish familiarity with the reader.

Cognitive Memory, Imagery and Visualization

The study by Bower (1972) drew distinctions between types of cognitive memory, and differences between remembering in imagery and remembering in propositions. The biggest distinction the author focused on was the “how versus what” (p. 52) in cognitive memory. Bower discussed that in imagery memory, we remember “how” something looked, tasted, felt, sounded or smelled, as distinct from “what” they resembled, tasted

like, sounded like, or what they smelled like. The primary focus of the study measured the differences between remembering in pictures versus remembering in words.

One problem with imagery is that an image "...of any particular instance could not possibly represent the concept in all its applications" (Bower, 1972, p. 56). An example Bower used to illustrate this was an image of a dachshund, and asked whether the image represented all dachshunds, all small dogs, all dogs in general, or whether it represented something else entirely. The representation of the image needed to be classified and clarified somehow.

In Bower's 1972 study, the researcher termed "imagination imagery" (p. 56) as the combining of images from memory to create a new image, for example, a memory image of a person and the memory image of an elephant can be imagined as an image of the person riding the elephant.

Bower (1972) found that when subjects tried to memorize pairs of words, including the words "dog" and "bicycle", subjects who used different methods of memorization had different success rates. The subjects who were instructed to visualize an image where the two representations interacted in some way, for example, a dog riding a bicycle, had significantly higher recall rates than did subjects who used rote memorization for a list of paired words.

Simon (1972) conducted a similar study, using paired words including "cigar" and "whale". Simon found that when research subjects visualized an interaction between images of the words, for example, a whale smoking a cigar, the research subjects had significantly higher recall rates when memorizing a list of words than did subjects who used rote memorization.

Kim and Tennant (1993) reported that one of the variables their study measured was the effectiveness of subjects using a visualization technique while shooting an air pistol. The research subjects were instructed to close their eyes and visualize the bull's eye of the target expanding. When the subjects felt that the target was getting larger, they were asked to simulate shooting the gun.

Another variable measured during the same study was a specialized breathing technique used by research subjects while shooting. Three groups had more accuracy and consistency in their shooting over the control group: the group of subjects who used visualization, the group that used specialized danjeon breathing, and the group that used visualization and danjeon breathing.

Cognitive Processes in the Perception of Visual Messages

Fleming (1970) studied cognitive processes in the perception of visual messages. One problem the researcher encountered was that very few reliable taxonomies existed for use in his experiments regarding pictorial messages using iconic signs. The researcher found few consistent measurable variables to use as reference points while conducting his study. The researcher sampled forty textbooks in four subject areas. His analysis was the basis for the formation of thirteen categories of elements in the illustrations. Examples of elements analyzed were shading, textual captions, and number of elements in the illustration. Fleming's study attempted to establish a systematic method of categorizing textbook illustrations and emphasized the difficulty of categorizing subject matter containing numerous variables. The study concluded that further perceptual research was needed to assist designers and users of visual instructional materials.

Spatial Structure and Memory

Asch's study (as cited in Fleming, 1970) noted that spatial dimension or structure had an effect on memorization. Syllables placed in a triangular pattern were memorized more consistently than a linear string of three syllables placed in one location. The syllables placed at the vertices of the triangles were recalled more often than syllables placed at adjacent points of the triangles. This study suggested that recall of information can be manipulated through visual spatial placement strategies of textual information.

Bower (as cited in Fleming, 1970) found that meaningful spatial arrangement of words facilitated more frequent recall than did random arrangement of words. Over twice as many words were recalled by research subjects when the words were placed in a hierarchical structure than randomly arranged words.

Fleming (1970) found that spatial structure, the arrangement of words forming shapes of text, rather than the standard linear convention used, could be manipulated to affect perceptions of relationships between word pairs. Fleming tested different visual structures of words and found that textual elements in a circular structure were assigned cause/effect and greater/lesser relationships when the elements had arrows between them, and no relationship was reported between the elements when they were structured in a circular arrangement with no arrows present. Greater/lesser relationships were reported as textual elements when they were arranged in a vertical-linear arrangement as opposed to when the elements were in a horizontal-linear arrangement.

Visualization and Schools

Forrest (as cited in Williams, 1998) reported that "visual recall" (p. 87) was the ability to reconstruct a visual image after exposure to visual stimuli. He stated that visual

recognition was vital to technology-based learning, with emphasis on computer-based instruction. Forrest stated that visual imagery was an ability that may require less mental energy than verbalization, and used the example of people dreaming in images, not words. For some people, referred to by Williams as “visualizers” (p. 91), concrete maps, graphs and charts as well as many other graphic tools were more easily interpreted, using smaller mental schemata than textual information. Williams quoted Forrest (p. 88) as stating that “Visualization is the goal of efficient visual information processing”. Visual imaging included the ability to draw conclusions about visual stimuli without the necessity of verbalizing it, and allowed for the application of imagery to tasks (Williams, 1998).

Horton (1980) and Ragen (as cited in Williams, 1998) stated that schools focus attention on textual information processing development and do not adequately address student’s visual information processing development needs.

Ragen (as cited in Williams, 1998) stressed the need for the development of student’s visualization capabilities and the importance these capabilities had on student learning. Williams (1998) called for continued examination of visual imagery, cognitive processes, and their impacts on education.

Models, Visualization, and Ability

Morgan and Welton (1992) described visual models as diagrams used to simplify descriptions. Used to summarize and explain, models help ensure that messages are received as intended.

Baker and Talley’s two studies used physical (as cited in Hill & Obenauf, 1979). The study measured prospective science teachers’ use of visualization as a cognitive

process. The researchers found that the use of physical models in instruction of first-year college chemistry students enhanced performance on spatial visualization and on questions classified as above recall on Bloom's taxonomy of learning. The researchers advocated the use of physical models in the teaching of chemistry and that models facilitated the development of imagery.

Brainerd (as cited in Hill & Obenauf, 1979) suggested that imagery was under-investigated as a dependent variable in learning.

Hill and Obenauf (1979) reported their replication of Baker and Talley's 1972 the study, finding that a visualization program was effective in enhancing problem-solving abilities of first-year college chemistry students. The research subjects were given a series of exercises using concrete models used in chemistry instruction to assist the students in the visualization of complex molecular structures. The exercises were designed to increase the students' spatial visualization abilities. The control group was given a set of reading assignments only, without the use three-dimensional models. The students were then tested using the Thurston Paper-Folding Test and the Tisher-Dale test. Hill and Obenauf found that subjects exposed to the three-dimensional models of complex molecular structures scored higher on visualization tests, indicating that visualization abilities can be developed in students.

Smith and Schroeder (as cited in Smith & Litman, 1979) found that fourth graders, regardless of gender, performed better on spatial visualization tasks after receiving instruction designed to enhance this ability, and performed better than subjects who received no instruction.

Robichaux (2000) reported multiple studies have shown that student's spatial visualization capabilities can be improved through classroom instruction.

Seng, Seokhoon, Yeo, and Alan (2000) investigated whether students with high, medium, or low spatial visualization abilities had preferences in learning styles. Learning styles investigated in this study included concrete experience, abstract conceptualization, reflective observation, and active experimentation. The researchers did not find statistically significant evidence that students had preference in learning modes with respect to their spatial visualization capabilities. These findings were contrary to earlier research findings.

Visual Literacy

Horton (1980) cited eleven authors clarifying visual literacy as having three main principles: that visuals are a language used similarly to verbal language; that a visually literate person has the ability to read and write visual material; and that a visually literate person has the ability to process visual information.

Flory (as cited in Spillman, Linder & Goforth, 1983) referred to visual syntax elements as the perceptual base, and that awareness of these perceptual elements and exploration of them through formal instruction helped children develop visual language skills. Often limited to discussion by art teachers, the author asserted that cross-disciplinary discussion of visual language elements should be conducted by teachers to help young students. The use of story-maps was suggested in this article. This method of encouraging young children to sketch the main events of a story they read was used to develop visualization skills. The children were instructed to develop the sequence of the

main ideas of the story, sketch them, and later use these sketches as visual aids to tell their story to the class.

An article by Lappan (1984) explained that the majority of math students' experience with three-dimensional objects came from working within two-dimensional media (Appendix N). The author stated that many students cannot "read" the two-dimensional pictorial representations of three-dimensional objects with proficiency. An example given was a set of twelve cubes stacked in two even layers, with six cubes per layer. When an isometric drawing of the stack of cubes was presented, the students usually made two types of errors. They either counted the faces of the cubes showing and answered that sixteen cubes were in the stack, or they counted the cubes showing and answered that ten cubes were in the stack. Either way, the common visualization error the students made was that they failed to count the hidden cubes, indicating that they did not visualize them. Lappan stated that to accomplish the task of visualizing the hidden cubes, the students must pass between concrete experience - seeing the cubes that are exposed in the illustration, and abstractions - visualizing the hidden cubes.

Gombrich (as cited in Ute, 1998) "...calls ours a 'visual age' in which we are bombarded with pictures from morning till night" (p. 3).

An article by Kirsch (1992) stated that the ability to read graphics was an important skill and that people are expected to know how to retrieve information from graphics in today's modern society. The author stated that the volume of data presented to people had grown over the years. Understanding graphic representation of information is an important skill because effective graphics simplify data by reducing it to essential elements.

Bertin (as cited in Kirsch, 1992) wrote that learning is facilitated by graphics that reinforce content by creating a mental image, which reduces effort required for remembering and processing.

Kirsch (1992) stated that most readers are untrained to read graphic representation of information, and that it is not valid to assume that readers understand the messages presented in graphical form as readily as they understand textual material. Kirsch wrote that this is a result of the educational system's emphasis on textual reading. The author stated that students' graphic reading skills are assumed, relying on intuition rather than formal training.

Beauchamp and Dowd (1992) wrote that most definitions of visual literacy include sections stating that visual literacy involves the interpretation and creation of visual communication, that visual literacy skills can be learned, and that these skills can improve a person's communication abilities.

Wileman (as cited in Beauchamp & Dowd, 1992) noted that students learn at different levels of ability, skill and experience, and that visuals designed to communicate at the student's ability level are more effective. Factors affecting the effectiveness of the graphic representation included the type of visual used, the method in which it was presented, and the individual student's ability to understand the message of the visual representation.

Wileman, Dwyer, and others (as cited in Beauchamp & Dowd, 1992) identified levels of visualization. The symbols used in the graphic representation of this visualization fell into categories. Wileman identified three broad categories: verbal symbols, described as nouns, definitions, and descriptions; graphic symbols, described as

arbitrary graphics or graphics related to conceptual representation; and pictorial symbols, described as illustrations, drawings, and photographs. Dwyer identified four broad categories of visual illustrations: simple line drawings, detailed shaded drawings, photographs of models, and realistic photographs.

“Visual literacy is the ability to process the elements of and to interpret visual messages; the ability to understand and appreciate the content and purpose of any image, as well as its structural and aesthetic composition” (Robinson, 1992, p. 223). This definition of visual literacy was developed by a professor and used in the course description for a visual literacy class at Northern Illinois University. A survey of visual and media literacy, the course dealt with the encoding and decoding of visual messages. The professor wrote that visual literacy is an important skill for all adults to have, “... and that the development of visual literacy actually changes the way a person thinks, responds to their environment, teaches and learns” (Robinson, 1992, p. 225). Robinson advocated that development of visual literacy was vital to students’ development.

A visual literacy course description from Florida State University read “Visual literacy is the learned ability to interpret visual messages accurately and to create such messages” (Heinich, Molenda, & Russell, as cited in Rezabek, 1992, p. 231). The authors described visual literacy as being in parallel with reading and writing in print literacy.

Rezabek (1992) also pointed out that visual literacy was a skill set that can be learned. Visual literacy is not left to intuition. It is taught at the university level to educators interested in developing their communication skills using visual means. The author further stated that little or no artistic talent was required to be visually literate, and that visual literacy incorporated a variety of proficiencies.

Fredette (1992) listed the importance of using visual imagery in thinking and learning in her course description for a class offered at the University of Pittsburgh. The course description emphasized the importance of the ability to recognize multiple meanings ascribed to visual messages. This course description delineated the concept of visual thinking into three overlapping arenas: mental imagery, visual perception, and visual expression.

Notable about this distinction regarding the need to have the ability to recognize multiple meanings ascribed to visual messages relates to definitions of technical writing. One of the parameters of technical writing is that there can be only one specific interpretation of the message contained in technical writing (Burnett, 1990). Technical writing must not have multiple meanings; technical communication is accurate, precise, and leaves no room for interpretation. Fredette's approach regarding the importance of the ability to recognize multiple meanings ascribed to visual messages was invaluable in the development of technical visual documentation.

“To operate effectively in the field of technical communication, today's students require extensive training in the creation, analysis, and design of information for both domestic and international audiences, for both paper and electronic environments” (Kostelnick & Roberts, 1998, p. xv).

Visual Operations Management

Stocker (2002) wrote of a visual imaging tool used in industry called Visual Operations Management, also referred to as VOM. Visual Operations Management is the practice of using visual aids to communicate messages to workers to overcome language barriers and to efficiently convey information in industrial settings. Types of messages

include company and governmental policies, modes of operation, procedures, and instructions. These messages can be communicated non-verbally using VOM. One objective of VOM is the rapid communication of procedures to new employees.

One application of VOM described by Stocker (2002) was the use of large electronic flow charts used in factories to communicate problems in process and manufacturing lines. Indicator lights in wall-mounted flow charts alert personnel to problems in the workflow as they arise, allowing quick response and more efficient operations.

Technology Education and Visual Imagery

Bell (1993) wrote an article discussing the fact that most Technology Education teachers in the profession at the time the article was written were products of the Industrial Arts era. Bell discussed how the Industrial Arts approach to visual communication used curriculum focused on particular technologies associated with mediums of visual communication. Printing, graphic arts, and mechanical drawing were mentioned as technologies and procedures included in the Industrial Arts teacher education clusters at some universities.

Bell went on to discuss how the approach to those technologies in the preparation of Industrial Arts teachers "...did not provide an understanding of how people visually communicate or how, in a graphic sense, images communicate their meaning" (p. 9).

Bell stated that the transition from Industrial Arts to Technology Education has been slow and that "...the mistakes of the past should not be repeated in the education of students for an information age" (p. 9). Bell stressed the need for 21st century students to have the capability and knowledge of how people visually communicate.

Chapter 3

Methodology

Introduction

This chapter will include information about how the sample was selected, a description of the sample, and the data collection instrument used. In addition, data analysis procedures will be given. The chapter will conclude with the methodological limitations.

Selection and Description of the Sample

A cluster sampling method was used for this study. Sixth-grade students enrolled in the Introduction To Technology class at Samuel Morse Middle School in Milwaukee, Wisconsin, during the 2003/2004 school year were selected as prospective participants.

A detailed description of the study's objectives, data collection methods, data analysis, and potential implications was written and discussed with the administration at Samuel Morse Middle School. Written consent to conduct the research study at the school was granted by the administration.

All students in the Introduction To Technology classes were given a general description of the study. A consent form was distributed to the students, signed by the students, and collected by the researcher.

A consent form describing the study was sent home with every student enrolled in the class. The consent forms, signed by the students' legal guardians, were returned to the researcher by the students.

Instrumentation and Data Collection

The instrumentation and data collection for this study involved the use of a design unit presented to the sixth-grade Introduction To Technology class at Samuel Morse Middle School.

Teachers and student teachers at Samuel Morse Middle School, Milwaukee, Wisconsin, were told by the school's administration to locate and develop pre-engineering units to present to the students. The Design Unit developed for this study and used to teach pre-engineering principles to the middle school students was adapted from the same textbook used at Bradley Tech High School, Milwaukee, Wisconsin, in accordance with the Curriculum Articulation Agreement between Samuel Morse Middle School, Bradley Tech High School, and Milwaukee Area Technical College. This text book, *Technology*, Wright (2000), is used in all Introduction To Technology classes at Bradley Tech High School. Section Four of this textbook is titled "Problem Solving and Design in Technology". Section Four includes chapters nine through twelve, titled "The Problem Solving and Design Process", "Developing Design Solutions", "Evaluating Design Solutions", and "Communicating Design Solutions", respectively.

Section Four of this textbook was adapted to an academic level appropriate for sixth grade students as an introductory pre-engineering design unit by the researcher for use in this study (Appendix B). This introductory design unit was then illustrated by the researcher for use in this study (Appendix C).

The non-illustrated version of this design unit was presented to the control group and the illustrated version of the design unit was presented to the experimental group.

A copy of the design unit was distributed to each student in a three-ring, black vinyl covered binder. Each student received two adhesive labels. The students were directed to write “Design Portfolio” on one label, and their name and class hour on the other. The students placed the labels on the front cover of their design unit binders.

Both the control group and the experimental group were exposed to five display cases containing suggested items suitable to be used to meet functional and market criteria in their designs. Three of the display cases measured 18” x 24” and two of the cases measured 24” x 24”. The display cases were 5” deep and covered with 1/8” clear acrylic sheet. Items contained in the display cases included various examples of clips, chain, string, mirrors, chalkboard, metal, plastic, magnets, multiple examples of adhesive materials, and decorative items. These display cases were used to streamline the section of the design unit regarding gathering of information and research. Pictures of these display cases can be seen in Appendix O.

The mock-up section of the design unit was accomplished using rigid foam insulation, five hot melt glue guns, and four hot-wire cutters.

This introductory design unit had a block schedule consisting of eight 50 minute class periods.

Students completed worksheet activities during each of the first five class periods and placed them in the inside flap of the cover of their design portfolios.

Students built their mock-ups during the final two class periods.

Comparison of student performance using the non-illustrated, textual version and the illustrated version of the design unit as evidenced by successful completion of identical worksheet activities between the two groups was analyzed.

Data Analysis

The data collected during the research study was statistically analyzed using a computerized statistics package called SSPS-X for the PC.

Limitations

Limitations to this study included:

1. The potential problem of secondary school students attempts to please the researcher. Student compliance rather than objective answers to worksheet activity questions can skew research data.
2. Research participants may be influenced by external factors prior to participation in the research study, influencing responses. Communication between the two groups of participating students, or other prior knowledge of the study, may influence research subject's behavior.
3. A limitation of this study may have been the Hawthorne effect: the common phenomenon associated with human research where the research subjects behave differently than they otherwise would, simply because they are aware that they are being observed.
4. This research study was limited by time, budget, and sample size. One class of sixth grade students was available at Samuel Morse Middle School for the control group, and one for the experimental group, during the timeframe allotted by the researcher.

5. The quality of graphic reproduction in the illustrated version of the design unit was a limiting factor. Black and white photo-copies were used to produce the student design portfolios rather than four-color printing or color photo-copies.

6. Behavioral issues involving the experimental group were a limiting factor. The experimental group of sixth-grade students had class right after their lunch period. The students consistently came to class wound-up and with less serious attitudes than the second-hour control group. Additionally, the experimental group's class was larger than the control group's. The control group had twenty-nine students while the experimental group had a class size of thirty-nine students, leading to still more class management distractions. Considerably more class time was spent dealing with student behavior with the experimental group than with the control group.

7. The control group had a more homogeneous set of academic skills and interests than did the experimental group. The control group was a French-Immersion Group, selected as a class due to their participation in a curriculum wide bi-lingual program of study. The remainder of the sixth-grade class, a group having more heterogeneous academic skills and interests, composed the experimental group.

Chapter 4

Results

Introduction

The purpose of this study was to measure the effectiveness of adding rich, highly graphic illustration to a design unit for use in a pre-engineering section of a Technology Education course presented to sixth grade students at Samuel Morse Middle School in Milwaukee, Wisconsin during the 2003/2004 school year. The study compared the performance of two classes of sixth grade students on identical worksheet activities after completion of identical content material presented to the two groups in different formats. Statistical comparison of the student's performance on the worksheet activities has indicated reliable information relating to the effectiveness of adding rich, highly graphic illustration to the pre-engineering design unit.

This pre-engineering design unit addressed two main subgroups of the design process: 1) Concepts about design, and 2) Ability to design. The Concepts of Design section of the design unit was broken down into the following categories:

- a) discrimination between the technological problem and the solution, b) clear definition of an authentic technological problem, and c) differentiation between different types of information used in the design process.

The ability to design section of the design unit was broken down into the following categories: a) brainstorming, b) attentiveness to design criteria, and c) sketching of design solutions.

The second hour class was presented the textual, non-illustrated version of the design unit as a control group. The second hour class had twenty-eight students. The sixth hour class was presented with the illustrated version of the design unit as the

experimental instrument. This group had thirty-seven students. One student in the sixth hour group answered no worksheet activity questions and completed no work. This student will not be counted in any of the following tables. Additionally, the total number of completed worksheet activities varied due to student absences and failure to do make-up work, as listed in Table 1

Table 1

Students Missing Entire Worksheet Activities

	<u>Worksheet 1</u>	<u>Worksheet 2</u>	<u>Worksheet 3</u>
Control Group	0	0	4
Treatment Group	0	2	2

Discrimination Between Problems and Solutions

The first section of the unit introduced the design process and outlined the steps necessary to identify a technological problem. This section placed emphasis on the importance of the ability to distinguish between a design problem and the solution, and how people's tendency to jump to conclusions can restrict creativity during the design process. After reading the section of the design unit regarding the distinction between a technological problem and the solution to the problem, the students were directed to complete Worksheet Activity One: Defining The Technological Problem in their design portfolios.

Table 2

Correct Student Responses To Worksheet 1

Question	Control			Treatment		
	F	n	%	F	n	%
1	27	28	.964	30	36	.833
2	25	28	.893	29	36	.806
3	26	28	.929	31	36	.861
4	23	28	.821	29	36	.786
5	22	28	.786	33	36	.916

Table 2 indicates that the control group and the treatment group scored very well on Worksheet 1, suggesting good comprehension of the concept presented in the first section of the design unit. The consistently high scores for each question by both groups of students also suggest a high level of engagement and student participation in the class activity. While the scores were high for both groups, it is interesting that neither group scored higher than the other on all items. The scores for questions four and five have approximately inverse scores between the two groups.

Definition of an Authentic Technological Problem

This section of the design unit dealt with the importance of the ability to clearly define a technological problem. The students were given a scenario outlining the problem of how messy lockers at their school waste time and make it difficult for them to find things in

their lockers. The students were given a list of some of the items kids often keep in their lockers. After reading the section of the design unit regarding the importance of the clear definition of a technological problem, the students were directed to complete Worksheet Activity Two: Defining The Technological Problem in their design portfolios. After description of a technological problem, the students were asked to clearly define the technological problem on their student activity worksheets.

Student's whose answers very clearly defined the problem – statement of the problem without extraneous information – were scored two points. Student's whose answers somewhat clearly defined the problem, where the problem was stated but the student included extraneous information in their response, were scored one point. Vague and off-target responses included mention of portions of the problem scenario but did not clearly state the technological problem or had nothing to do with the technological problem at all. Vague or off-target responses were scored 0 points.

Table 3

Student Scores On Worksheet 2

Points	Control			Treatment		
	F	n	%	F	n	%
0	9	28	.321	4	34	.118
1	10	28	.357	21	34	.618
2	9	28	.321	9	34	.265

Table 3 shows that while a consistent number of students were able to state the technological problem very clearly from both the control group and the treatment group, even more students were able to only state the problem somewhat clearly. The table also indicates that in the control group, there were as many students unable to state the problem at all as there were students able to state it very clearly. The treatment group had approximately half as many students incapable of stating the problem with any clarity as the control group, and had twice as many students capable of stating the problem with some clarity than the control group had.

Discrimination Between Different Types of Information

This section of the design unit dealt with the gathering of information needed in the design process. The students read in their design portfolios about different types and sources of information gathered while researching a technological design solution. At the end of this section, the students completed Worksheet 3 in their design portfolios. The

worksheet had examples of the types of information students would gather during their research. The students were directed to discern what type of information was listed in the example and to write their answers in the space provided on the worksheet.

Table 4

Correct Student Responses To Worksheet 3

Question	Control			Treatment		
	F	n	%	F	n	%
1	10	24	.417	13	34	.382
2	14	24	.583	27	34	.794
3	18	24	.750	24	34	.706
4	11	24	.458	20	34	.588
5	11	24	.458	27	34	.794

The scores in Table 4 indicate that student performance fell considerably on Worksheet 3. The consistently low scores suggest a problem with either the delivery of the content material or the phrasing of the questions, rather than one format being more effective than the other. Questions two and five do, however, indicate slightly better student performance by the treatment group than the control group.

Brainstorming, Rough Sketching, Refined Sketching

In this section of the design unit students wrote down all ideas they had relating to a technological solution to the design problem. Students were directed to write down all

ideas that came to them as a preliminary step in solving the design problem. The students were encouraged to be as creative as possible, and to not concern themselves with how their brainstorming ideas may have seemed unusual or impractical at first, as the ideas could be refined later. The students were instructed to fill out their brainstorming worksheets with as many ideas as possible.

The design unit presented the steps of brainstorming, rough sketching and refined sketching as separate, distinct steps in the design process. The students were provided with separate worksheets for each level; brainstorming, rough sketching and refined sketching. As the students progressed through this phase of the design process, they found that when performed thoroughly, the three above mentioned steps tended to overlap. The brainstorming of ideas often required rough sketches to convey the idea, and the rough sketches were used to construct the refined sketches. Staying within the parameters of the necessary criteria to solve the design problem, the students created their library of ideas as packets of ideas and sketches and filed them in their design portfolios.

The student design packets were scored on the quantity of brainstorming ideas and the attention to the design criteria. Student scores are listed in Table 5.

Table 5

Student Scores on Brainstorming, Rough Sketching, and Refined Sketching Activity

<u>Quantity of Brainstorming Ideas</u>						
Quantity	Control			Treatment		
	F	n	%	F	n	%
4	3	28	.107	5	36	.139
3	5	28	.179	13	36	.361
2	12	28	.429	15	36	.417
1	8	28	.286	3	36	.083

<u>Attentiveness to Design Criteria</u>						
Quantity	Control			Treatment		
	F	n	%	F	n	%
8	3	28	.107	5	36	.139
7	1	28	.036	0	36	.000
6	3	28	.107	4	36	.111
5	0	28	.000	5	36	.139
4	5	28	.179	9	36	.250
3	7	28	.250	10	36	.278
2	9	28	.321	3	36	.083
1	0	28	.000	1	36	.028

The treatment group had a higher percentage of students recording three brainstorming ideas, and a lower percentage of students with only a single idea. The treatment group also had higher percentages of attentiveness to design criteria in six out of eight quantity categories in Table 5.

Detailed Sketch of Technological Design Solution

After the students refined their technological solutions to the design problem, they picked their favorite one and added details to their sketch. The details included sizes of design features, locations of design features and overall dimensions of the locker organizer as measured by length, width and depth. Additional details on the drawings included material specifications. The students detailed drawings were scored according to sizes and locations listed on the drawings, as well as attention to design criteria. Student scores are listed in table 6.

Table 6

Student Scores on Detailed Sketch of Technological Design

<u>Size and Location of Features</u>						
Quantity	Control			Treatment		
	F	n	%	F	n	%
3	6	28	.214	13	36	.361
2	13	28	.464	17	36	.472
1	9	28	.321	6	36	.167

<u>Attentiveness to Design Criteria</u>						
Quantity	Control			Treatment		
	F	n	%	F	n	%
8	3	28	.107	4	36	.111
7	1	28	.036	1	36	.028
6	3	28	.107	4	36	.111
5	2	28	.071	7	36	.194
4	3	28	.107	7	36	.194
3	8	28	.286	10	36	.278
2	8	28	.286	3	36	.083
1	0	28	.000	1	36	.028

The student scores in Table 6 indicate approximately equal student performance between the control and treatment groups in detailing the size and location of features on their drawings. Both groups did consistently as well as each other in attentiveness to design criteria. Table 6 also indicates that scores for attentiveness to design criteria were relatively evenly spread over the range of possible scores in that category.

Research Question

Null Hypothesis: The addition of rich, highly graphic illustration to a design unit presented to sixth-grade students at Samuel Morse Middle School in Milwaukee, Wisconsin during the 2003/2004 school year will result in no significant difference in student performance.

Alternate hypothesis: The addition of rich, highly graphic illustration to a design unit presented to sixth-grade students at Samuel Morse Middle School in Milwaukee, Wisconsin during the 2003/2004 school year will result in a significant difference in student performance.

Composite Scores and Results

Individual student composite scores (Table 7) were analyzed using the two-sample with equal variance t-test formula. The results include the t-statistic of 1.155 and a Critical two-tailed value of 1.999, with a P value of .252. The calculated t-statistic of 1.155 represents a non-significant difference in composite scores of student performance on the treatment instrument. The conclusion of this researcher was that the null hypotheses was not rejected, whereas, the addition of rich, highly graphic illustration to a design unit presented to sixth-grade students at Samuel Morse Middle School in

Milwaukee, Wisconsin during the 2003/2004 school year resulted in no significant difference in student performance.

Chapter 5

Summary, Conclusion and Recommendations

Introduction

This chapter will summarize the research study, draw a conclusion from the information revealed by the study, and will conclude with recommendations for continued research.

Summary

While there have been several studies during the past century regarding learning styles, cognition, the use of different media in education, teaching strategies, curricula design, educational theory, and levels of learning in different domains, little recent research relating to these areas in the field of Technology Education have been found. Successful completion of the pre-clinical experience as a requirement for the Bachelor of Science degree and Master of Science degree in Technology Education at the University of Wisconsin-Stout involves university students constructing and presenting a graphical display in a school setting as a learning tool. The graphical learning tool constructed and presented by the university students must be well constructed, attractive, and convey a technically accurate message clearly, among other things.

This research study measured student performance through the addition of rich, highly graphic illustration to a design unit presented to sixth-grade students at Samuel Morse Middle School in Milwaukee, Wisconsin during the 2003/2004 school year. The study compared the performance of two classes of sixth grade students on identical worksheet activities, after completion of identical content material presented to the two groups in different formats.

Conclusion

It is the conclusion of this researcher that the addition of illustration to a design unit had no significant impact on student performance in the sixth grade classes at Samuel Morse Middle School, Milwaukee, Wisconsin during the 2003/2004 school year. This researcher concludes that further research is needed in the field of Technology Education regarding the construction and implementation of textual, graphical, and combined technical/graphical educational media.

Recommendations

Further research into the addition of rich, highly graphic illustration to Technology Education units is recommended. Areas of further investigation may include:

- 1) Does class size have a direct relationship to student engagement and learning while using an illustrated design unit?
- 2) Would use of the same illustrated design unit result in significantly more student performance in a middle school class with fewer than thirty-seven students?
- 3) Does the use of a French-Immersion class of sixth-grade middle school students as a control group in a study measuring student performance using an illustrated Technology Education design unit result in elimination of homogeneous variance in cluster sample selection, resulting in skewed data?
- 4) Does significantly less student performance occur in large middle school Technology Education classes right after the student's lunch period?
- 5) Does presentation of an illustrated design unit to middle school students right after their lunch period contribute to behavior problems?

6) Do students perceive an illustrated design unit as something so unusual and different than what they are accustomed to seeing in their curriculum that they do not engage in it?

7) Would students who were accustomed to using richly illustrated versions of Technology Education units achieve significantly higher levels of performance?

8) Does the presentation of an illustrated Technology Education unit help a large, unruly class of sixth grade middle school students achieve the same level of performance that a well-behaved class would using a textual version of the same unit?

These questions, among others, are recommended for further research relating to the addition of illustration to technical material as a learning aid.

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Appendix A

The following pages contain the written assignment for Module No. 4 in its entirety.

(Anderson, 2002, n.p.)

Technology Education

Field Experience & Seminar

190-360

Module No. 4: Making a Laboratory Poster or other classroom media

Technology teachers often have groups of students performing different activities in the laboratory at once. As a result, he or she can be bombarded with a wide range of questions if he or she does not communicate laboratory procedures clearly. Sometimes, clear and complete instructions are not enough. Students forget steps in a process, settings on equipment, and locations for materials. Teachers often compensate for their students' short memories by providing handouts outlining laboratory procedures. Unfortunately, out of class of 24 students, several students are bound to misplace their procedure list. Therefore, teachers often post important laboratory procedures in strategic places in their laboratories. Such poster or other classroom medias promote safety, enable students to help themselves, and free the teacher to interact with students in more meaningful ways. The purpose of this module is to provide you an opportunity to begin developing some laboratory skills by developing a poster or other classroom media that outlines a laboratory procedure under the direction of an experienced technology teacher.

Objective

Given a topic by their cooperating teacher, students will be able to develop a poster or other classroom media that describes a laboratory process and meets the standards provided to the cooperating teachers satisfaction (see evaluation criteria).

Assignment

The first step in developing a poster or other classroom media for a technology laboratory activity is to identify an objective that needs to be reinforced. For example, your cooperating teacher might want his or her students to be able to develop black and white prints in the darkroom. Consequently, the teacher might need a poster or other classroom media outlining the development process. In addition to listing the steps in the process, the poster or other classroom media would also promote proper laboratory techniques (using tongs to move the print from one chemical bath to the next) and safety considerations (do not touch your eyes with wet hands). Ask your cooperating teacher for an objective or topic that you can address. Make sure you limit your poster or other

classroom media to one topic and only one topic. Addressing more than one process on a poster or other classroom media can result in confusion on the part of the viewers.

Once you have identified a topic, discuss with your cooperating teacher a location for the poster or other classroom media when it is finished. This will help you determine the appropriate size for the poster or other classroom media and its element.

The next step is to develop a clear and concise title to capture the viewer's attention. Next, outline the contents for the poster or other classroom media (e.g., steps, safety considerations, appropriate laboratory techniques) and identify appropriate artwork. Keep the wording and artwork simple and in the viewer's language. Once you have all elements of the poster or other classroom media, develop a rough layout. Keep the principles of design in mind when working on this step. Obtain expert feedback about your design by sharing it with your cooperating teacher before proceeding to the next step.

After your cooperating teacher has approved your design and its contents, gather the materials that you will need to make your poster or other classroom media. Assemble the poster or other classroom media in accordance to your design. Show the final product to your cooperating teacher for feedback and request a final evaluation. Lastly, provide your cooperating teacher with your final product and, if appropriate, request permission to place the poster or other classroom media in its intended working location.

Please include a photograph or sample of your product when the evaluation form is turned-in.

Evaluation (Turn this signed form in to the TECED-360 Instructor)

The classroom instructor, applying the standards listed below, will evaluate your poster or other classroom media. The following scale will be used rate the quality of your work. Any portion of the assignment that is judged to be unsatisfactory will need to be revised.

O for Outstanding

The narrative is rich with details, very insightful, and well written.

S for Satisfactory

The narrative adequately addresses the question and is relatively easy to read.

U for Unsatisfactory

The narrative presents an incomplete, vague, or rough response to the question.

Design Standards

Scale

The poster or other classroom media:

- | | | | |
|---|---|---|---|
| 1. is well constructed or designed | O | S | U |
| 2. conveys its message quickly and clearly. | O | S | U |
| 3. is attractive and holds the viewer's attention. | O | S | U |
| 4. uses proper spelling and written communication skills | O | S | U |
| 5. features directions that are technically accurate. | O | S | U |
| 6. is visually legible when viewed in proper context. | O | S | U |
| 7. is attentive to neatness and quality. | O | S | U |
| 8. can be easily displayed or used as originally intended | O | S | U |

Classroom Instructor Signature: _____

Date:

Comments:

Appendix B

The following pages contain the textual version of the design unit in its entirety.

(Wright, 2000, pp. 133-178)

The Design Process

Problem (Opportunity)

Identifying the Problem

Define the Problem

Gather Information/Establish Criteria

Developing the Solution

Develop Possible Solutions

Refine Possible Solutions

Evaluating the Solution

Selecting the Best Solution

Model the selected Solutions

Communicating the Solutions

Interpret the Solutions

Present the Solutions For Approval

Solution

Solving A Problem

When you have a problem with something, how do you solve it?

Sometimes we can design things to solve a problem we have. We can design things to make something easier to do.

Designing is a little like inventing. The difference between designing and inventing is that often we can make a design of something that has already been invented. We can change the design of something to make it different than something else. We MODIFY the design to make something the way we want it, but it may not be a whole new invention.

Cars are a good example of new designs. When new car models come out every year, we don't say that the car has been re-invented – the car was invented a long time ago – but new car designs come out every year.

When we have a problem – something we want or need to be made better

The answer to our problem is called a

SOLUTION.

On one side we have PROBLEM.

On the other side, we have a SOLUTION.

Solving The Problem

When we have a problem, and we think something could be designed to help us do something better, how do we come up with a new design?

How do people go from the problem to the solution? Do they just dream up a final product? When you go to the store and see all of the products on the shelves, do you think that these products just appeared to people out of the blue?

How do these products get designed?

Most often, solutions to problems do not just appear out of thin air.

Technological solutions rarely appear off the top of your head. While that can happen – we call that INTUITION, where the answer to a complex problem just comes to you, most often more is needed to solve technological problems.

Design Process

The process used to solve a technological problem and find a solution to the problem is called the DESIGN PROCESS.

Problem:

When a person wants or needs something and does not have what they want or need.

- 1) They have a goal.
- 2) No obvious way of reaching the goal.

Technological Problem Solving

What do we mean when we say TECHNOLOGICAL? Technology has to do with things made by people. Science is the study of natural things, while technology is the study of things made by people.

Not all problems are TECHNOLOGICAL. Other kinds of problem can be:

- Social – Problems with people; friends, family, neighbors, foreign countries, etc.
- Scientific – If you don't understand something from the natural world, for example, "What causes the rain to fall from certain types of clouds?"
- Ethical – If you find someone's personal property, should you return it to them?

If you have a TECHNOLOGICAL PROBLEM, you need to make tools or machines or build something to solve your problem.

PROBLEM = OPPORTUNITY

A technological problem is really an opportunity for you to find a solution.

How do you find a technological solution?

Through the DESIGN PROCESS.

Step One

Identify the problem.

Defining the problem is recognizing a need or want from people that can be solved through technology.

The first step is to identify the problem or opportunity.

In order to solve a technological problem or opportunity, the problem must be CLEARLY DEFINED.

If you don't know what the problem is exactly, you won't be able find the solution. The problem needs to be stated clearly.

You need to:

- Explain the situation that needs a technological solution.
- Establish the CRITERIA that the device must meet. (Criteria are like guidelines.)

Example Problem:

- We want to sell more Coke.
- We want to satisfy customers by selling Coke at convenient locations.
- We want to sell Coke ready to drink (cold), in one serving containers, at all hours, and not have pay a store clerk to be there sell the Coke and take the money.

The above parts of the problem are the Criteria – the details we need to satisfy to solve the problem.

What do you think the solution to this technological problem was?

Look at the problem again. Can you guess what the technological solution is to the problem is? Coke Machines (vending machines).

The problem had to be carefully stated, with all of the CRITERIA.

The problem assignment was not “Design a Coke Machine.” The problem was the above list of criteria that had to be satisfied to solve the problem.

Defining the problem is important. It may not seem like a big deal, but describing the situation is a big part of the design process.

Describing the problem is **not** describing the solution.

Be careful to describe the problem carefully, rather than describing the solution at first. If you are not careful in describing the problem rather than describing the solution, you can restrict creativity.

Example: “Design a device a person can sit on.” This is not the same as saying, “Design a chair.”

Can anyone tell why these are two different statements?

The problem in this case is that we “need something to sit on”,

Not “we need a chair”. We could design a bean bag to sit on, a wicker basket suspended from chains, a nice bench, or any number of things to sit on. If we told our design team to “Design a new kind of chair”, the design team would focus on chairs only. Our company could miss out on an opportunity to score big in the marketplace if we restricted creativity by poorly defining the problem. A new product came out two years ago that looks like a type of harness that hangs from a frame. It looks a little like a cross between a porch swing and a hammock. It is made to be sat on, but is clearly not a chair.

Worksheet 1: Defining The Technological Problem

Name _____ Date _____ Hour _____

Directions: Pick the statement below that best states a technological design problem statement. Circle the letter for each question you choose.

1. a) Design and develop a device that keeps food cold.
 b) Design and develop a refrigerator.

2. a) Design a device that allows easier dispensing of orange juice.
 b) Design an orange juice carton that has better flaps.

3. a) Design a stapler.
 b) Develop a solution to the problem of loose papers.

4. a) Mountain Dew bottles need to be designed with thinner glass
 because they are too heavy and cost too much to produce.
 b) Mountain Dew bottles need to be re-designed so they aren't as
 heavy and so they cost less to produce.

In the space below, write what you think the design problem is for the following:

Question) The company president has decided that we need to sell more Coke. We need to make the product more accessible (available) to customers at convenient locations. We want to make the product ready to drink (cold). We want to be able to sell our product even where there is no-one is on duty to sell it to the customer (self-serve availability). What do you think would be a good design solution to this problem?

Answer) Our design team should work on designing a

The Problem (Opportunity)

Kids at school each are assigned a locker. When you started here at Samuel Morse Middle School, you got your own locker. You were given the combination, and you keep all of your important stuff in it.

Have you ever noticed that it gets a little messy? Do you ever have any trouble finding stuff in it? Does there seem to be times when you want to talk to your friends, but you can't because you have to look for something in your locker? Do you think that maybe there is a better way to keep your locker organized? What if you could DESIGN or DEVELOP something that would help you keep all of your important stuff organized in your locker?

Wouldn't it be nice if you could come up with some idea to help you find your important stuff faster in your locker so you would have more time to get to class, and maybe even have some time to talk to your friends?

Wouldn't it be even better if you could help DESIGN or DEVELOP a product that could help kids all over the school to organize their lockers?

Think of the possibilities. What if you were on a design team that came up with the design for a locker organizer that was sold in stores?

Where do we begin?

If you look at the design unit, you will see that the first step is to

IDENTIFY THE PROBLEM.

Kids keep a lot of things in their lockers besides books and coats. What are some of the things you keep in your locker?

1. keys
2. your class schedule
3. pencils and pens
4. a mirror to see yourself
5. pictures of your friends, family, or pet
6. important notes to remind you of things, like homework assignments
or maybe something you have to remember to do later on in the week
7. something to write notes on
8. others: like maybe small change, phone numbers, decorative magnets,
candy or anything else that kids keep in their lockers.

Lockers At Morse Middle School

The locker that you were assigned at the beginning of the school year is actually a double locker system. The main locker measures 52" high by 6" wide by 16" deep. Your top locker measures 8 ¼" high by 13 inches wide by 16" deep.

The school has suggested that new lockers be installed next summer. Your new locker will be twice as wide as the one you have now. Where you see the little, narrow doors now, you will see a single, wide door. The new locker will be twice as big, so you will not need a top locker. The new wide doors will go all the way up to the top of the where the little locker is now.

The new locker dimensions, or sizes, will be 60" high by 13" wide by 16" deep.

The school needs you to come up with a

TECNOLOGICAL SOLUTION

to the problem of kids losing stuff in their lockers.

Worksheet 2: Defining The Technological Problem

Name _____ **Date** _____ **Hour** _____

Directions: Clearly define the problem in the space below.

The problem is

Establishing The Criteria

The first step in the design process is defining the problem. You did this carefully so you did not restrict creativity.

The next step is to ESTABLISH THE CRITERIA.

What are CRITERIA?

Criteria are the limits and characteristics that the device must meet.

Technical or engineering criteria are specific functions that must be met by the device. They are things that the device must do. They can also be any rules that are set down, like what the device must be made of.

Example of Functional criteria: The device must clear rain from the windshield of a moving automobile.

Do you notice that this functional criteria does not mention anything about wiping? The design and development of the windshield wiper was a solution to the design problem criteria. The need to remove rain from the windshield was the problem criteria. The wiper was the solution.

Types of Criteria:

- Functional Criteria - What the device must do.
- Production Criteria – Resources available to produce the device.

Examples of this include materials to make it out of, machines

available to use to make it, location of factories, production timeframe.

- Market Criteria – Rules set down so the product will sell. Example:
The product (device) must be priced for \$4.99 or less.
Other examples of marketing criteria include the color, size and shape of the device.
- Environmental Criteria – things that affect the environment. For example: The device must not emit too much carbon dioxide.

**CRITERIA ARE REQUIREMENTS THAT MUST BE MET IN
THE DEVELOPMENT AND PRODUCTION OF OUR PRODUCT.**

Criteria Types:

- 1) Functional
- 2) Production
- 3) Market
- 4) Environmental

The Definition of the Problem and the List of Criteria provide the basis for the Design Process.

These two important steps provide an outline for the next phase –
Gathering of Information.

The definition of the problem and the list of criteria are followed up with the gathering of information. Much information is needed to develop a product. The design team gathers as much information as possible to help them develop a design. The designers gather information that will help them come up with a good design. Types of information that will help the designers include:

- **Historical Information** – What types of products have been developed in the past that meet some or all of our criteria? Has this design problem, or a similar problem, come up in the past?
- **Scientific Information** – What are the possible solutions allowed by the laws of nature and physics? Background information regarding the physical possibilities of a design must be known. For example: welding, glues, thermal properties – the way something expands, shrinks or maybe cracks when it gets very hot or cold, or other scientific information about the materials and processes we may want to use in the production of our product.
- **Technological Information** – The design team needs to be up-to-date on current production technology. What are the best kinds of machines to cut our material on? How should we weld, rivet, glue or

otherwise assemble our product? Can we make it out of a single part or do we need to make separate parts and assemble them?

- Legal Information – Does a patent already exist for this device?

The above types of information –

- Historical Information
- Scientific Information
- Technological Information
- Legal Information

are gathered by doing RESEARCH. Researching (gathering information) is done at the library, by going to tradeshow where companies set up booths to promote their latest machines and technology, by interviewing people, looking through catalogs, surfing the Internet, among others. There are many ways to gather information about our product design.

Worksheet 3: Gathering Information

Name _____ Date _____ Hour _____

Much information must be gathered in the development of a technological product. Types of information that must be gathered include:

- Historical
- Scientific
- Technological
- Legal

Directions: In the space below, write what kind of information each example is.

1) Has a product like this ever been built before?

2) When was a product that is similar to this one made? Where was it made?

3) Can we use polypropylene rubber for our skateboard wheels? Will this type of rubber wear out too fast on concrete sidewalks?

_____.

4) What kinds of new machines can we buy to assemble the bearings to our rubber skateboard wheels?

_____.

5) Do any patents exist for the type of skateboard wheel we want to develop?

_____.

A Suggested Solution

A possible solution to the problem of messy, disorganized lockers at Samuel Morse Middle School is a

LOCKER ORGANIZER.

What is a Locker Organizer?

A locker Organizer is something that you can develop to help keep your important stuff where you want it to stay in your locker. When you open your locker door, you want to be able to quickly look and know where everything is. You don't want to have to waste a lot of time looking for stuff, and you want your locker to look nice too.

Criteria For The Locker Organizer

Where have you heard that word before?

The **FUNCTIONAL CRITERIA** for the Locker Organizer include:

- 1) It must hang on the inside of the locker door.
- 2) It must be attached without damaging the locker door.
- 3) It must be removable at the end of the school year.
- 4) It must be removed from the locker door without damaging the Locker Organizer or the door.

- 5) The Locker Organizer must stay attached to the inside of your locker door even if you accidentally slam your locker shut once in a while.

Additional **FUNCTIONAL CRITERIA** are that the Locker Organizer must have include spots for

- 6) Keys.
- 7) Your class schedule.
- 8) Pencils and pens.
- 9) A mirror to see yourself in.
- 10) Pictures of your friends, family, or pet
- 11) Important notes to remind you of things, like homework assignments or maybe something you have to remember to do later on in the week.
- 12) Something to write notes on.
- 13) Others: like maybe small change, phone numbers, decorative magnets, candy or anything else that kids keep in their lockers.

The **PRODUCTION CRITERIA** for the Locker Organizer are the materials and tools we will use. They are:

Available Materials:

1/8" thick Plexiglas
thick wood

1/4" thick Plexiglas
thin wood

sheet metal
plastic glue

hot melt glue	molded plastic	glass
cement	cork	ceramic tile
canvas	cloth	paper
cardboard	foam core	rubber
aluminum foil	acrylic (plastic) mirror	string
small chain	spring clips	magnet strips
two-sided tape	film containers	Velcro
dry-erase board	screws	nuts and bolts

Machines and Tools Available

scroll saw	band saw	hand saw
welder	molding machines	sheet metal bender
stamping press	hammer	pliers
scissors	heat strip machine	riveter

MARKET CRITERIA for the Locker Organizer is that it has to look nice.

We want people to want to buy our product, so we have to do a good, high quality job on our design. It also must be priced for \$9.99 or less.

ENVIRONMENTAL CRITERIA are that we need to use at least one recycled material in our design. We also must use production methods that don't cause too much pollution.

The gathering of:

- Historical
- Scientific
- Technological
- Legal

Information provides the background for the next step in the design process.

Developing Design Solutions

Product Design:

The development of devices or goods that people can use to satisfy a want or need.

After 1) defining the problem, 2) establishing criteria, and 3) gathering of information, the design team moves on to the next step 4) DEVELOPING DESIGN SOLUTIONS.

This phase of the product development is usually broken down into three main categories:

- a) Developing Preliminary Sketches
- b) Refining the Chosen Solutions
- c) Detailing the Best Solution

Imagineering

The design team members use their imaginations to come up with a number of solutions to the problem. First, the design team comes up with a number of preliminary solutions. Preliminary means “first”.

The process that the design team uses to come up with these preliminary solutions is called BRAINSTORMING.

BRAINSTORMING

The design team gathers into a group and lets their creativity run free.

Members of the group call out any ideas that pop into their heads.

Brainstorming means “Seeking creative solutions to an identified problem.”

During a brainstorming session, design team members call out all ideas that come to them. There are no bad ideas during a brainstorming session. All ideas are good ideas in a brainstorming session. Be as creative as possible.

Let your imagination soar. Try to solve the problem with as many ideas as you can. You can be as wacky as you want. You can refine the ideas later.

For right now, you want to get as many ideas down as you can. Do not worry if they are bad ideas or not - because in a brainstorming session, there are no bad ideas. As long as your ideas are focused on solving the problem, they can be as unusual as your imagination will allow. Remember to keep in mind the criteria as it was stated.

Tips for good Brainstorming:

- All ideas are good ideas. Even wacky or really goofy ideas can be refined later.
- Don't react or criticize anyone's ideas. This can lower creativity and make people not want to give ideas.

Brainstorming Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your BRAINSTORMING ideas here

Use as many sheets of paper as you need.

File All OF YOUR BRAINSTORMING IDEAS IN YOUR student portfolio.

Brainstorm now. Try to think of as many ideas as you can to solve the problem statement. Write your ideas below. You can sketch your ideas if that helps. Write little notes on the sketches so you will remember what your idea is later. Think of ideas that will solve the problem statement and meet the criteria. The functional criteria are what the device must do, and the technological criteria are how the device is made.

Brainstorming Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your BRAINSTORMING ideas here

Use as many sheets of paper as you need.

File All OF YOUR BRAINSTORMING IDEAS IN YOUR student
portfolio.

Brainstorming Work Sheet

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Brainstorming Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your BRAINSTORMING ideas here

Use as many sheets of paper as you need.

File All OF YOUR BRAINSTORMING IDEAS IN YOUR student
portfolio.

Rough Sketching

Draw Sketches of your ideas. The sketches are called “Rough Sketches” because the ideas are still in the unrefined state.

As you make rough sketches of your ideas, you are making a

LIBRARY OF IDEAS

Do not spend a lot of time making the rough sketches to look like to final product. The point of making rough sketches is to get the general idea down on paper. You want to get these ideas on paper so you can refine them later. Just make a picture of your ideas for now. After your rough sketches are made, the next step is called Refining the Ideas.

Rough Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your ROUGH SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your ROUGH SKETCHES in your student portfolio.

Rough Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your ROUGH SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your ROUGH SKETCHES in your student portfolio.

Rough Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your ROUGH SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your ROUGH SKETCHES in your student portfolio.

Rough Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions Record all of your ROUGH SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your ROUGH SKETCHES in your student portfolio.

Refining the Ideas

Take your rough sketches and select the most practical ones. Pick out the ones that seem to be the best ideas to solve the design problem. Work on these rough sketches that you like to make them better. This is called Refining. Make the sizes and proportions seem better. You can add features (parts) or get rid of ones you don't like. You want to take the best rough sketches now and make them look more like how the final product should look like.

A Refined Sketch is a Rough Sketch that you made better.

Not all of your rough sketches have to become refined sketches. You can drop any ideas that you think are not worth following up on. Spend your time now on the ideas that you think are best.

Refined Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your REFINED SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your REFINED SKETCHES in your student portfolio.

Refined Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your REFINED SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your REFINED SKETCHES in your student portfolio.

Refined Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your REFINED SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your REFINED SKETCHES in your student portfolio.

Detailed Sketch

The next step in the design process, after producing the rough sketches and the refined sketches, is to produce Detailed Sketches.

The rough sketches and the refined sketches give you a good idea of what your device will look like. Now you need to figure out where you will make your cuts in the material, where you will make the holes, grooves, lines or any other features your product will have.

The Detailed Sketch contains the locations and sizes of these features. The detailed sketch will have the actual sizes and measurements written right on the picture. That way, when you are making the product, you will know where to cut, drill, bend, or otherwise make (fabricate) the product.

Detailed Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your DETAILED SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your DETAILED SKETCHES in your student portfolio.

Detailed Sketch Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your DETAILED SKETCH ideas here.

Use as many sheets of paper as you need.

File All of your DETAILED SKETCHES in your student portfolio.

Modeling

The designer's favorite idea is now taken from being an idea on paper, the Detailed Sketch, to being a three-dimensional item called a Mock-Up.

A Mock-Up is a model of the device. The designer makes a mock-up out of Styrofoam or some other modeling material. The reason a mock-up is made is for the designer to be able to see the device in a 3-dimensional format that can be held in the hand and looked at better. This mock-up gives the designer a better idea of what the product will look like.

Making of the Mock-Up

A mock-up does not have to be an exact replica of the final product. The mock-up should, however, be a close resemblance of what the final product will look like. The mock-up model is made so the designers will get a better understanding of what the final product will look like. For this reason, you will want to do a good job when you make your mock-up.

Use your detailed sketch to make your mock-up. You will be using the foam provided in class. You may cut, punch holes, and glue the foam so that the mock-up matches your detailed sketch. You will present your model to the teacher for your final grade.

Appendix C

The following pages contain the illustrated version of the design unit in its entirety.

(Wright, 2000, pp. 133-178)

THE DESIGN PROCESS

Problem (Opportunity)

Identifying the Problem

Define the Problem

Gather Information/Establish Criteria

Developing the Solution

Develop Possible Solutions

Refine Possible Solutions

Evaluating the Solution

Selecting the Best Solution

Model the selected Solutions

Communicating the Solutions

Interpret the Solutions

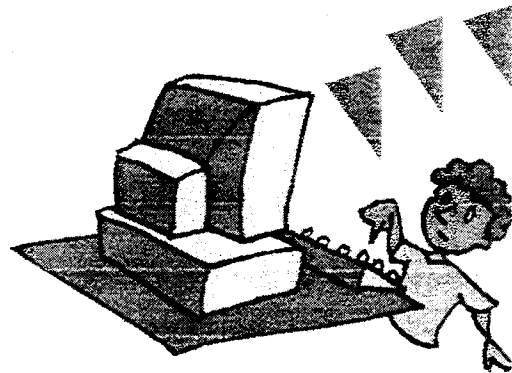
Present the Solutions For Approval

Solution

SOLVING A PROBLEM

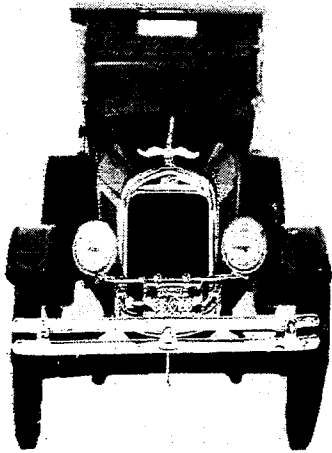
When you have a problem with something, how do you solve it?

Sometimes we can design things to solve a problem we have. We can design things to make something easier to do.

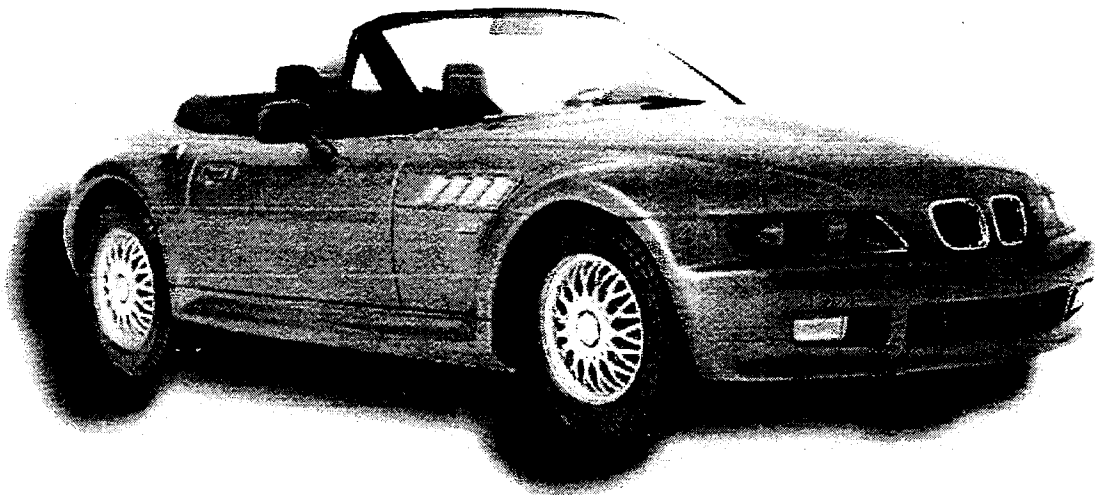


Designing is a little like inventing. The difference between designing and inventing is that often we can make a design of something that has already been invented. We can change the design of something to make it different than something else. We **MODIFY** the design to make something the way we want it, but it may not be a whole new invention.



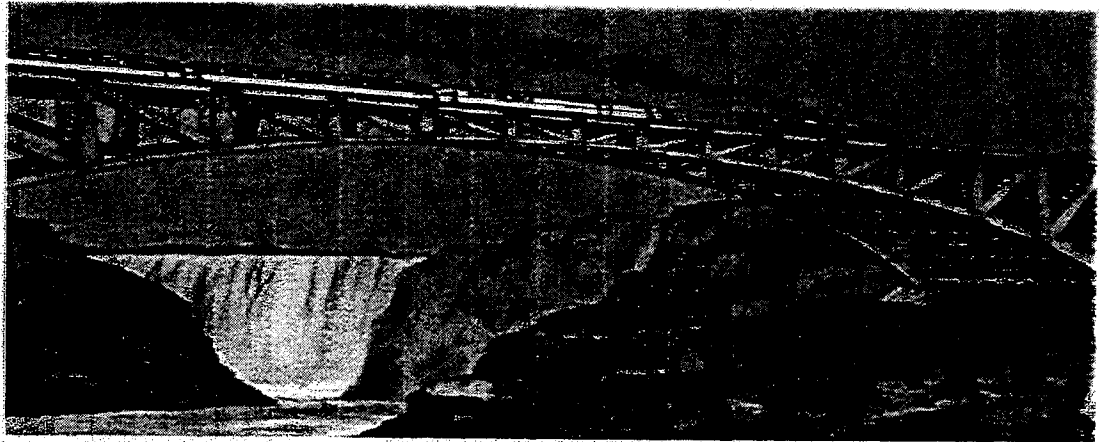


Cars are a good example of new designs. When new car models come out every year, we don't say that the car has been re-invented – the car was invented a long time ago – but new car designs come out every year.



When we have a problem – something we want or need to be
made better The answer to our problem is called a
SOLUTION.

On one side we have a
PROBLEM



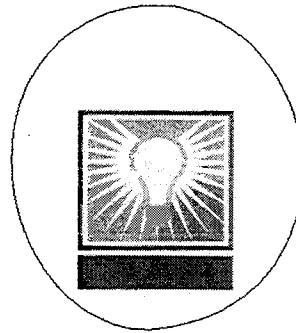
On the other side, we have a
SOLUTION.

SOLVING THE PROBLEM

When we have a problem, and we think something could be designed to help us do something better, how do we come up with a new design?

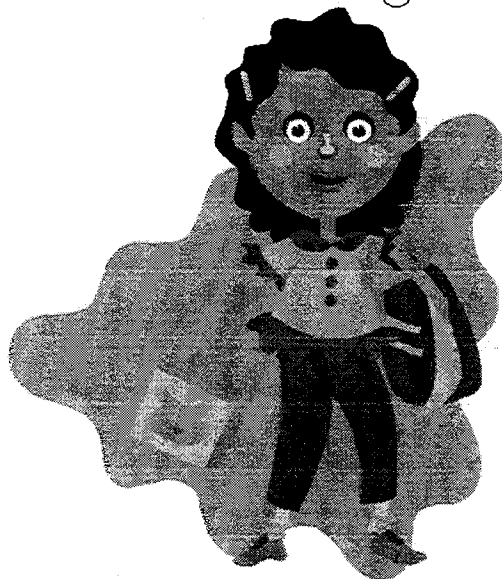
How do people go from the problem to the solution? Do they just dream up a final product? When you go to the store and see all of the products on the shelves, do you think that these products just appeared to people out of the blue?

How do these products get designed?



Most often, solutions to problems do not just appear out of thin air.

Technological solutions rarely appear off the top of your head. While that can happen – we call that



INTUITION, where the answer to a complex problem just comes to you, most often more is needed to solve technological problems.

DESIGN PROCESS

The process used to solve a technological problem and find a solution to the problem is called the **DESIGN PROCESS**.

Problem:

When a person wants or needs something and does not have what they want or need.

1) They have a goal.



2) No obvious way of reaching the goal.



Technological Problem Solving

What do we mean when we say TECHNOLOGICAL? Technology has to do with things made by people. Science is the study of natural things while technology is the study of things made by people



Not all problems are TECHNOLOGICAL.
Other kinds of problem can be:



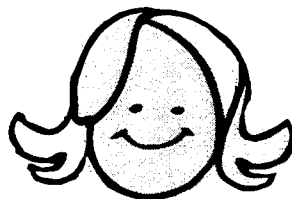
- **Social** – Problems with people; friends, family, neighbors, foreign countries, etc.

- **Scientific** – if you don't understand something from the natural world,

for example, "What causes the rain to fall from certain types of clouds?"



- **Ethical** – If you find someone's personal property, should you return it to them?

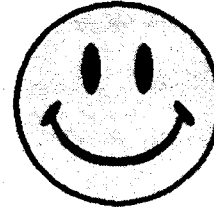


If you have a **TECHNOLOGICAL PROBLEM**, you need to make tools or machines or build something to solve your problem.



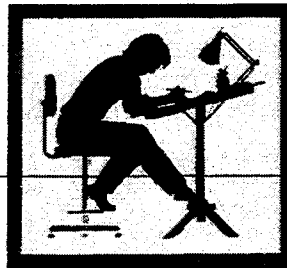
PROBLEM = OPPORTUNITY

A technological problem is really an opportunity for you to find a solution.



How do you find a technological solution?

Through the **DESIGN PROCESS**.



Step One

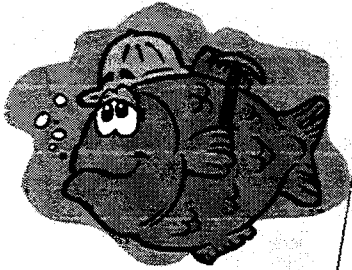
IDENTIFY THE PROBLEM.

Defining the problem is recognizing a need or want from people that can be solved through technology.

The first step is to **IDENTIFY THE PROBLEM** or opportunity.

In order to solve a technological problem or opportunity, the problem must be **CLEARLY DEFINED.**

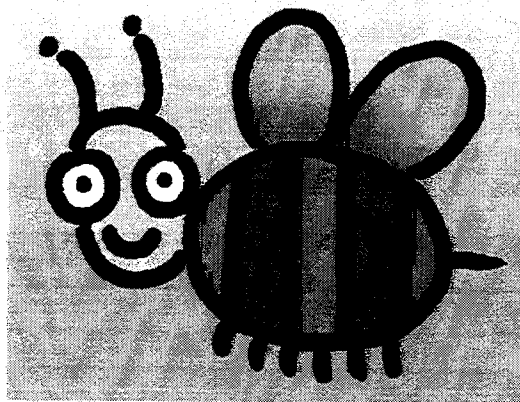




If you don't know what the problem is exactly, you won't be able to find the solution. The problem needs to be stated clearly.

You need to:

- Explain the situation that needs a technological solution.
- Establish the **CRITERIA** that the device must meet. (Criteria are like guidelines.)



Example Problem:

- We want to sell more Coke.
- We want to satisfy customers by selling
convenient locations.



Coke at

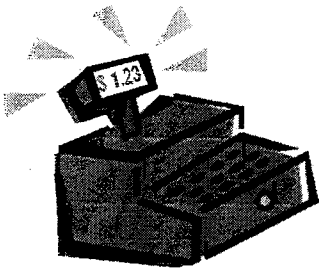
- We want to sell Coke ready to drink (cold), in
containers, at all hours, and not have pay a store clerk



one serving

to be there to sell the

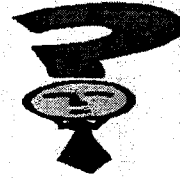
Coke and take the money.



DEFINE THE PROBLEM

Look at the problem again. Can you guess what the technological solution is to the problem is?

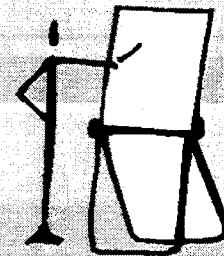
Coke Machines (vending machines).



The problem had to be carefully stated, with all of the CRITERIA. The problem assignment was not "Design a Coke Machine." The problem was the above list of criteria that had to be satisfied to solve the problem.

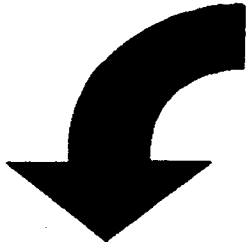
Describing the problem is not describing the solution. Be careful to describe the problem carefully, rather than describing the solution at first. If you are not careful in describing the problem rather than describing the solution, you can restrict creativity.

Example: "Design a device a person can sit on."
This is not the same as saying, "Design a chair."

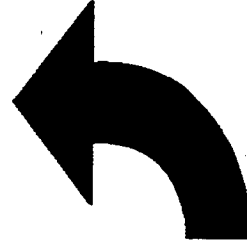


Can you tell why the next two statements are different?

If we told our design team to “**Design a new kind of chair**”, the design team would focus on chairs only.



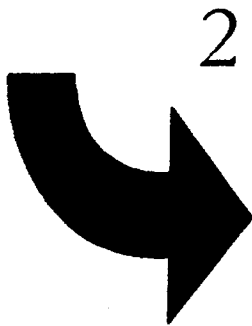
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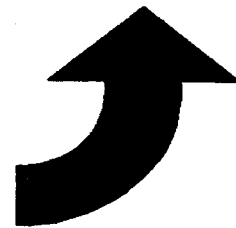
The problem in this case is that “We need something to sit on”,
Not “We need a chair”.

We could design a bean bag to sit on, a wicker basket suspended from chains, a nice bench, or any number of things to sit on.



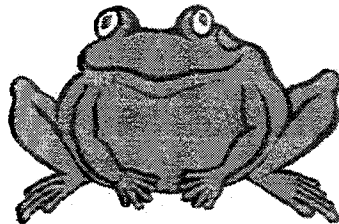
2

3





Complete Worksheet 1 from
your Design Portfolios.



Worksheet 1: Defining The Technological Problem

Name _____ Date _____ Hour _____

Directions: Pick the statement below that best states a technological design problem statement. Circle the letter for each question you choose.

1. a) Design and develop a device that keeps food cold.
 b) Design and develop a refrigerator.

2. a) Design a device that allows easier dispensing of orange juice.
 b) Design an orange juice carton that has better flaps.

3. a) Design a stapler.
 b) Develop a solution to the problem of loose papers.

4. a) Mountain Dew bottles need to be designed with thinner glass
 because they are too heavy and cost too much to produce.
 b) Mountain Dew bottles need to be re-designed so they aren't as
 heavy and so they cost less to produce.

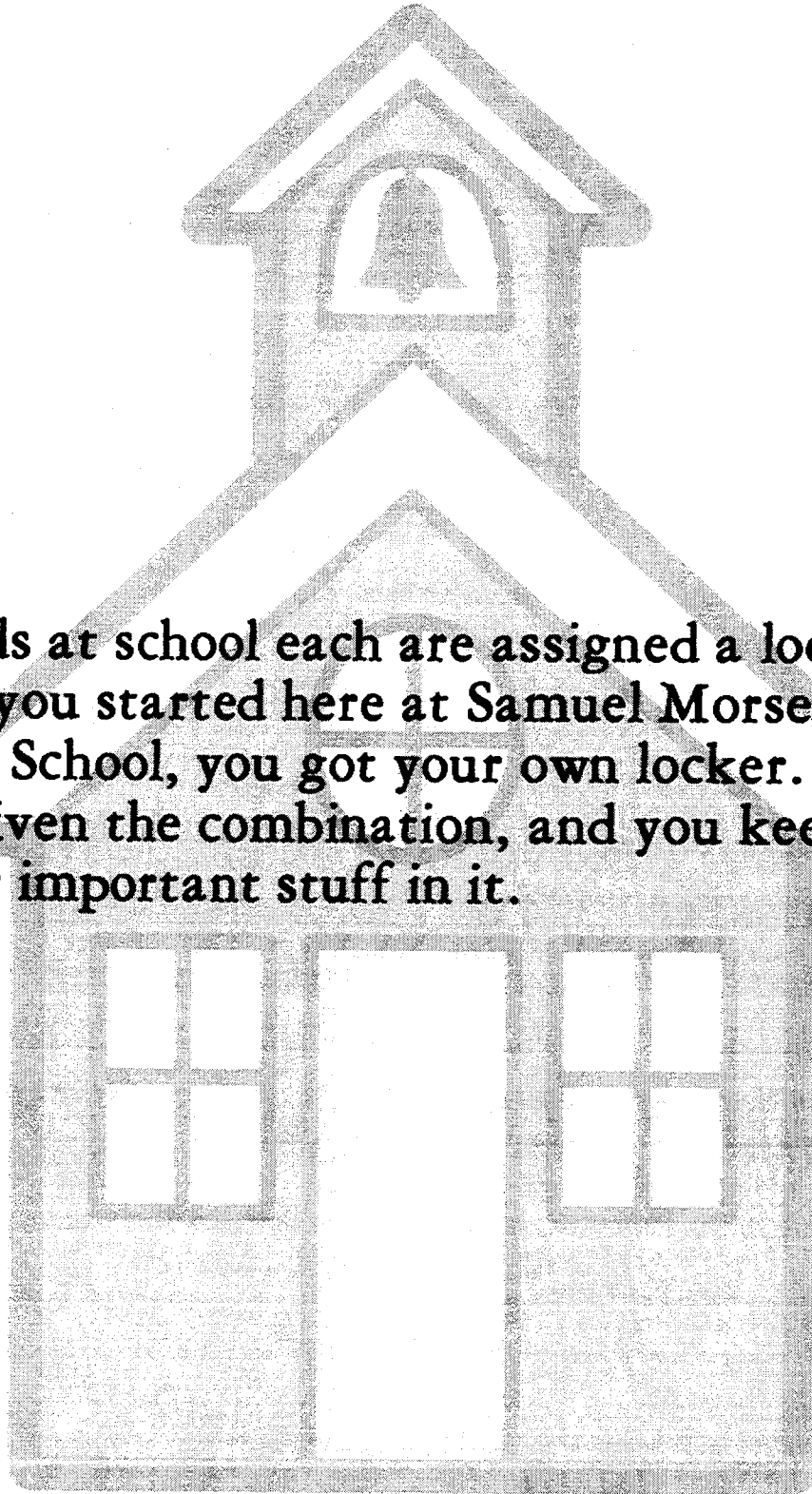
In the space below, write what you think the design problem is for the following:

Question) The company president has decided that we need to sell more Coke. We need to make the product more accessible (available) to customers at convenient locations. We want to make the product ready to drink (cold). We want to be able to sell our product even where there is no-one is on duty to sell it to the customer (self-serve availability). What do you think would be a good design solution to this problem?

Answer) Our design team should work on designing a

The Problem (Opportunity)

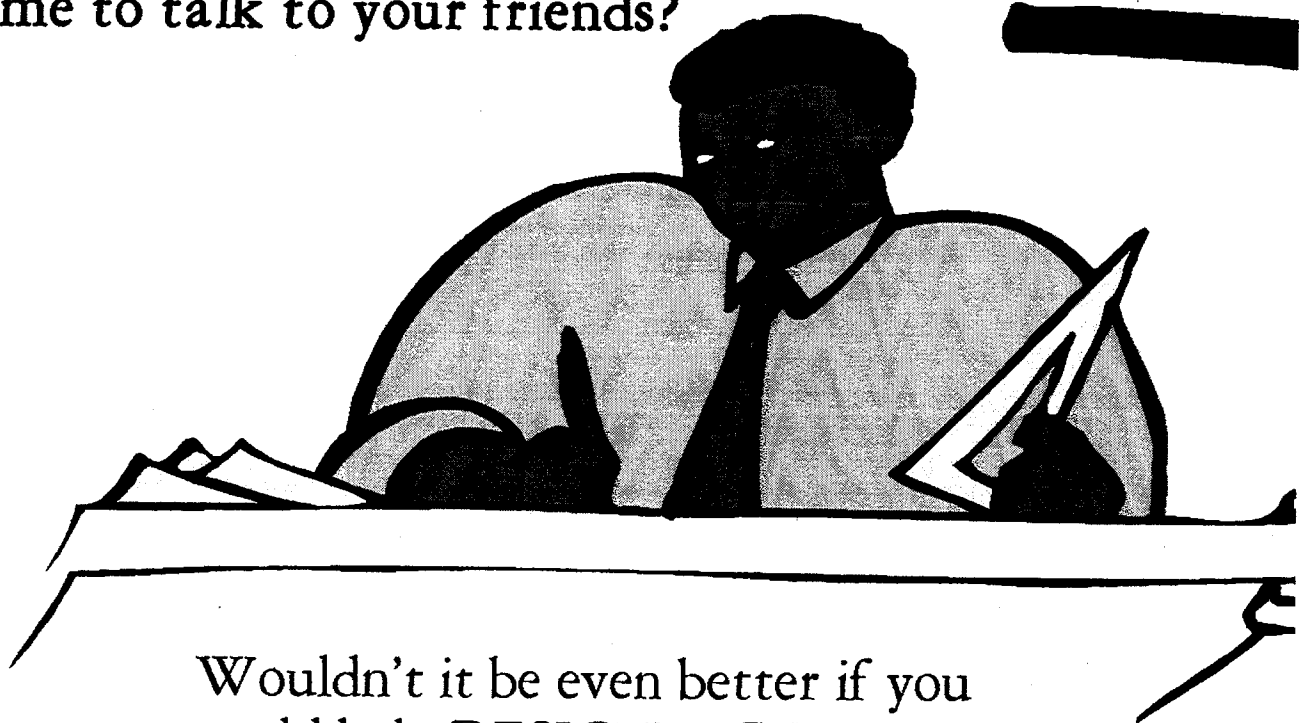
Kids at school each are assigned a locker. When you started here at Samuel Morse Middle School, you got your own locker. You were given the combination, and you keep all of your important stuff in it.





Have you ever noticed that it gets a little messy? Do you ever have any trouble finding stuff in it? Does there seem to be times when you want to talk to your friends, but you can't because you have to look for something in your locker? Do you think that maybe there is a better way to keep your locker organized? What if you could **DESIGN** or **DEVELOP** something that would help you keep all of your important stuff organized in your locker?

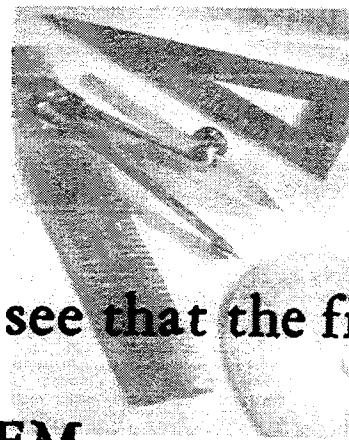
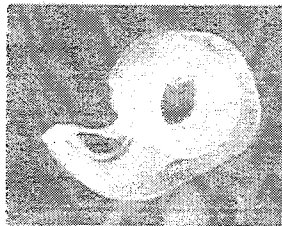
Wouldn't it be nice if you could come up with some idea to help you find your important stuff faster in your locker so you would have more time to get to class, and maybe even have some time to talk to your friends?



Wouldn't it be even better if you could help DESIGN or DEVELOP a product that could help kids all over the school to organize their lockers? Think of the possibilities. What if you were on a design team that came up with the design for a locker organizer that was sold in stores?



Where do we begin?

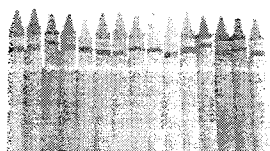
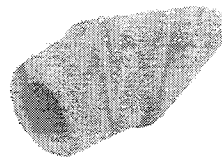
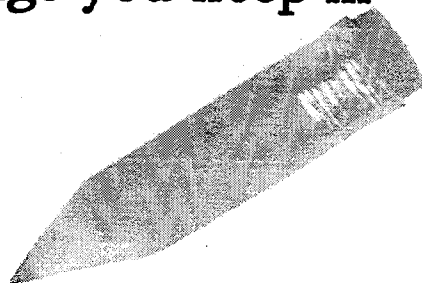
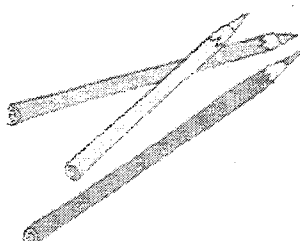


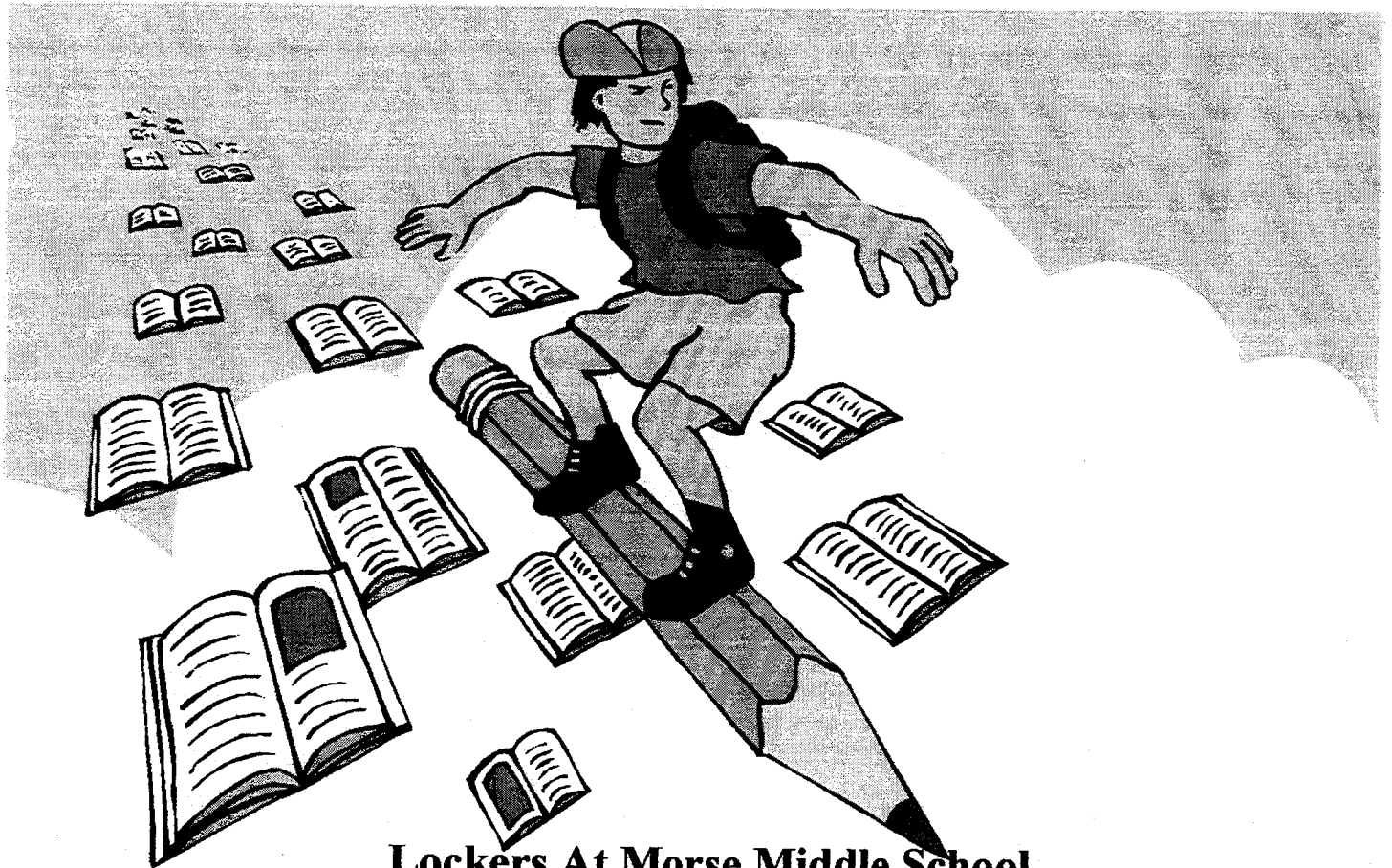
If you look at the design unit, you will see that the first step is to

IDENTIFY THE PROBLEM.

Kids keep a lot of things in their lockers besides books and coats. What are some of the things you keep in your locker?

1. keys
2. your class schedule
3. pencils and pens
4. a mirror to see your self
5. pictures of your friends, family, or pet
6. important notes to remind you of things, like homework assignments or maybe something you have to remember to do later on in the week
7. something to write notes on
8. Other: like maybe small change, phone numbers, decorative magnets, candy or anything else that kids keep in their lockers.





Lockers At Morse Middle School

The locker that you were assigned at the beginning of the school year is actually a double locker system. The main locker measures 52" high by 6" wide by 16" deep. Your top locker measures 8 1/4" high by 13 inches wide by 16" deep.

The school has suggested that new lockers be installed next summer. Your new locker will be twice as wide as the one you have now. Where you see the little, narrow doors now, you will see a single, wide door. The new locker will be twice as big, so you will not need a top locker. The new wide doors will go all the way up to the top of the where the little locker is now.

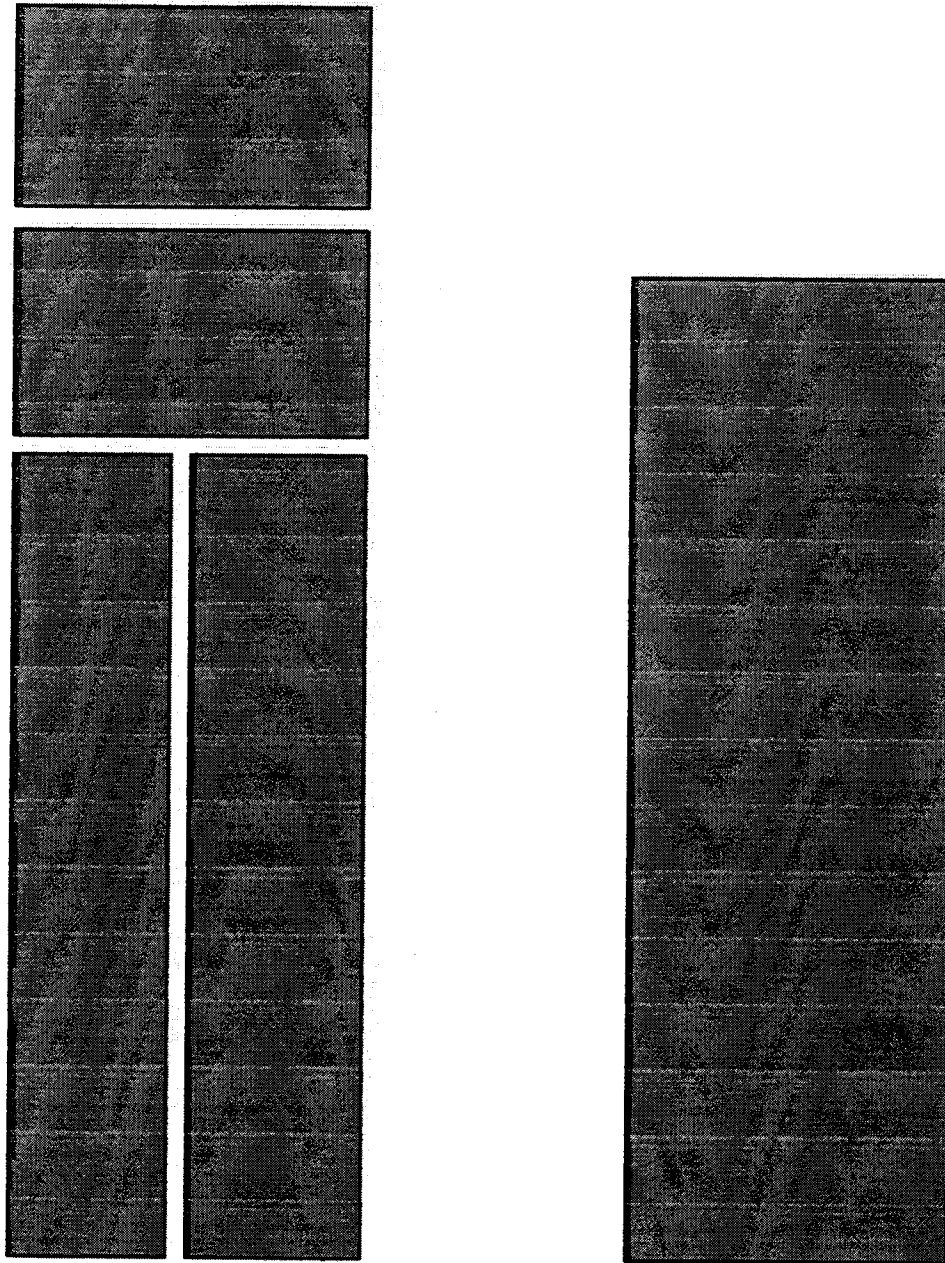
The new locker dimensions, or sizes, will be 60" high by 13" wide by 16" deep.

The school needs you to come up with a

TECNOLOGICAL SOLUTION

to the problem of kids losing stuff in their lockers.

Lockers At Samual Morse Middle School

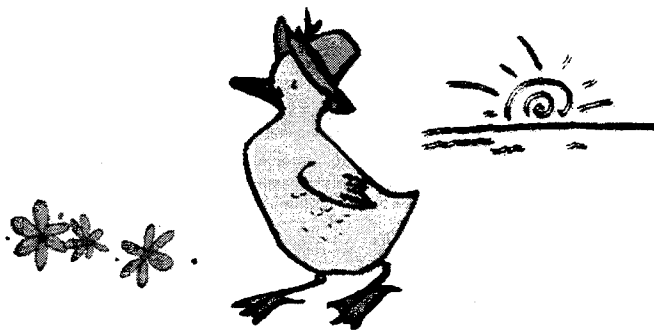


OLD

NEW



Complete Worksheet 2 from
your Design Portfolios.



Worksheet 2: Defining The Technological Problem

Name _____ **Date** _____ **Hour** _____

Directions: Clearly define the problem in the space below.

The problem is

CRITERIA

What are Criteria?

The first step in the design process is defining the problem. You did this carefully so you did not restrict creativity.

The next step is to ESTABLISH THE CRITERIA.

What are CRITERIA?

Criteria are the limits and characteristics that the device must meet. Technical or engineering criteria are specific functions that must be met by the device. They are things that the device must do. They can also be any rules that are set down, like what the device must be made of.

Example of Functional criteria:

The device must clear rain from the windshield of a moving automobile.

Do you notice that this functional criteria does not mention anything about wiping?

The design and development of the windshield wiper was a solution to the design problem criteria.

The need to remove rain from the windshield was the problem criteria.

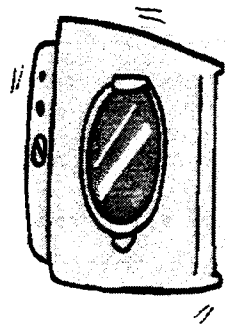
The wiper was the solution.

TYPES OF CRITERIA

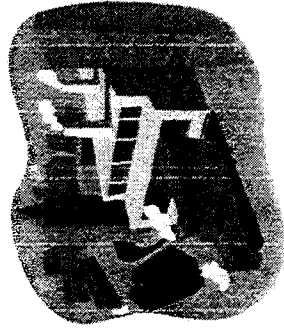
- Functional Criteria - What the device must do.
- Production Criteria – Resources available to produce the device. Examples of this include materials to make it out of, machines available to use to make it, location of factories, production timeframe.
- Market Criteria – Rules set down so the product will sell. Example: The product (device) must be priced for \$4.99 or less.
Other examples of marketing criteria include the color, size and shape of the device.
- Environmental Criteria – things that affect the environment. For example: The device must not emit too much carbon dioxide.

**CRITERIA ARE REQUIREMENTS THAT MUST BE MET IN THE
DEVELOPMENT AND PRODUCTION OF OUR PRODUCT.**

Criteria Types:



FUNCTIONAL



PRODUCTION



MARKET



ENVIRONMENTAL

The Definition of the Problem and the List of Criteria provide the basis for the Design Process.

These two important steps provide an outline for the next phase –

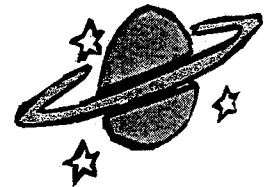
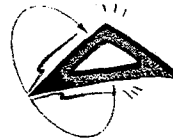
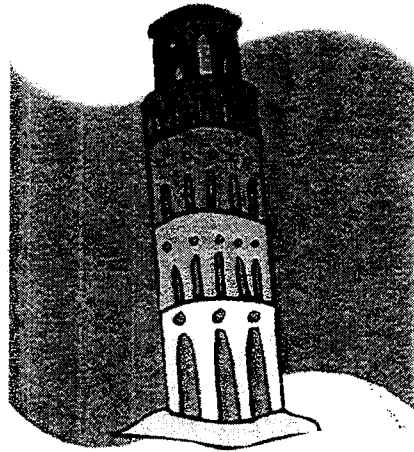
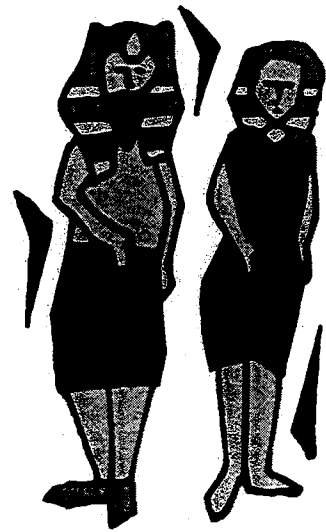
GATHERING

O F

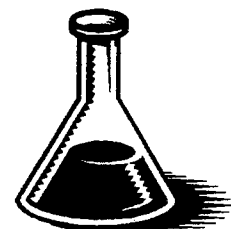
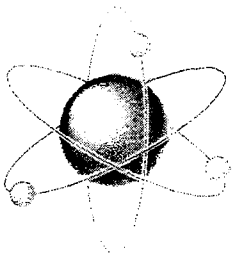
INFORMATION

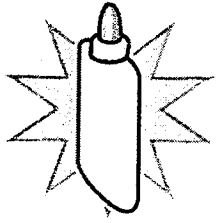
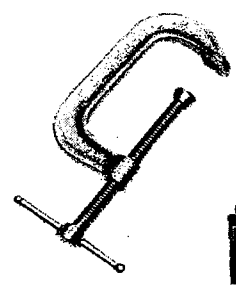


Historical Information – What types of products have been developed in the past that meet some or all of our criteria? Has this design problem or a similar problem come up in the past?

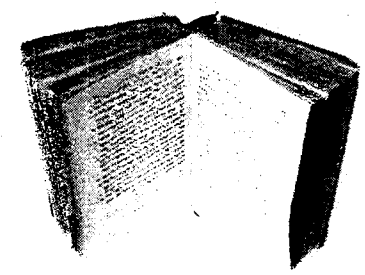
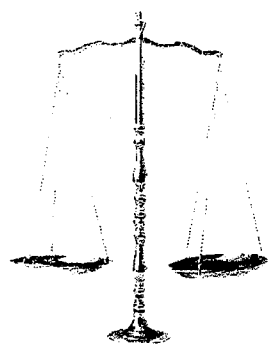
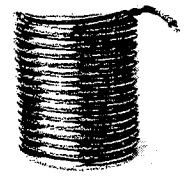
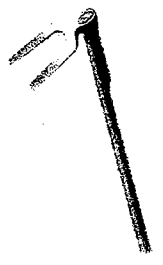
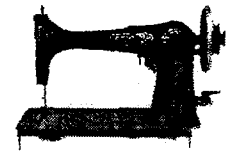


Scientific Information – What are the possible solutions allowed by the laws of nature and physics? Background information regarding the physical possibilities of a design must be known. For example: welding, glues, thermal properties – the way something expands, shrinks or maybe cracks when it gets very hot or cold, or other scientific information about the materials and processes we may want to use.

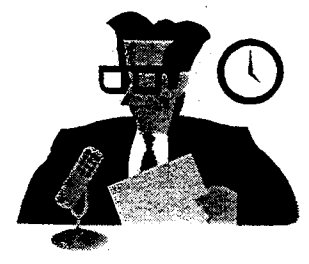




Technological Information -The design team needs to be up-to-date on current production technology. What are the best kinds of machines to cut our material on? How should we weld, rivet, glue or otherwise assemble our product? Can we make it out of a single part or do we need to make separate parts and assemble them?



Legal Information – Does a patent already exist for this device?



The definition of the problem and the list of criteria are followed up with the gathering of information. Much information is needed to develop a product.

The design team gathers as much information as possible to help them develop a design.

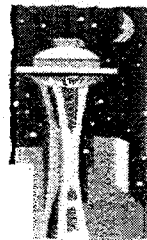
Types of information that will help the designers include:



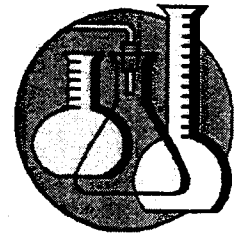
Historical Information



Legal Information



Technological Information



Scientific Information

Research

The **INFORMATION** THAT
YOU GATHER



HISTORICAL



SCIENTIFIC

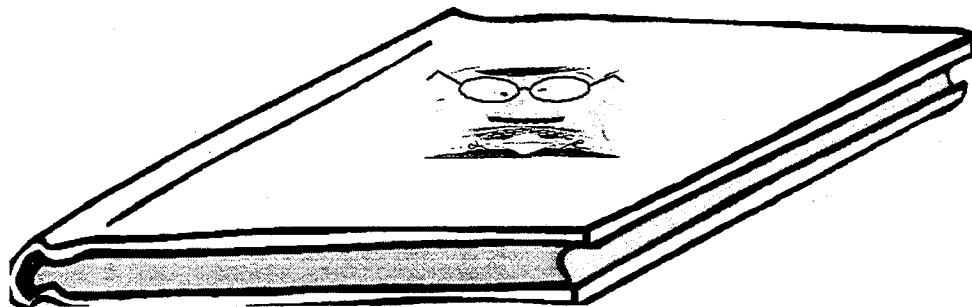


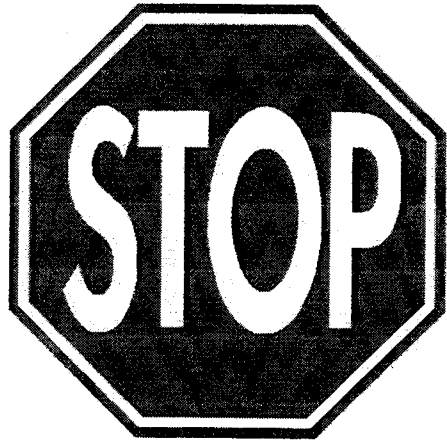
TECHNOLOGICAL



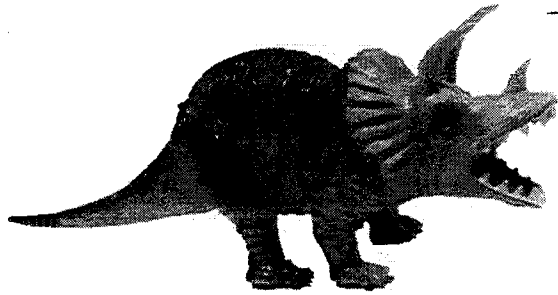
LEGAL

is gathered by doing **RESEARCH**. This is done by going to the library, by going to trade shows where companies set up booths to promote their latest technology, by interviewing people, by looking through catalogs, and by surfing the Internet. There are many ways to gather information about our product design.





Complete Worksheet 3 from
your Design Portfolios.



Worksheet 3: Gathering Information

Name _____ Date _____ Hour _____

Much information must be gathered in the development of a technological product. Types of information that must be gathered include:

- Historical
- Scientific
- Technological
- Legal

Directions: In the space below, write what kind of information each example is.

1) Has a product like this ever been built before?

_____.

2) When was a product that is similar to this one made? Where was it made?

_____.

3) Can we use polypropylene rubber for our skateboard wheels? Will this type of rubber wear out too fast on concrete sidewalks?

_____ .

- 4) What kinds of new machines can we buy to assemble the bearings to our rubber skateboard wheels?

_____ .

- 5) Do any patents exist for the type of skateboard wheel we want to develop?

_____ .

A Suggested Solution

A possible solution to the problem of messy, disorganized lockers at Samuel Morse Middle School is a

LOCKER ORGANIZER.

What is a Locker Organizer?

A locker Organizer is something that you can develop to help keep your important stuff where you want it to stay in your locker. When you open your locker door, you want to be able to quickly look and know where everything is. You don't want to have to waste a lot of time looking for stuff, and you want your locker to look nice too.

Criteria For The Locker Organizer

Where have you heard that word before?

The **FUNCTIONAL CRITERIA** for the locker organizer include:

- 1) It must hang on the inside of the locker door.
- 2) It must be attached without damaging the locker door.
- 3) It must be removable at the end of the school year.
- 4) It must be removed from the locker door without damaging the Locker Organizer or the door.
- 5) The Locker Organizer must stay attached to the inside of your locker door even if you accidentally slam your locker shut once in a while.

Additional **FUNCTIONAL CRITERIA** are that the Locker Organizer must have include features for

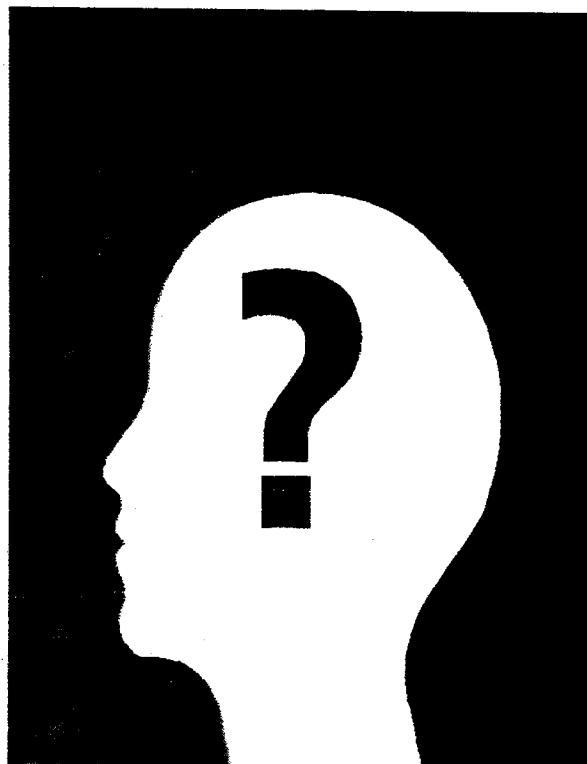
- 1) Keys.
- 2) Your class schedule.
- 3) Pencils and pens.
- 4) A mirror to see your self in.
- 5) Pictures of your friends, family, or pet
- 6) Important notes to remind you of things, like homework assignments or maybe something you have to remember to do later on in the week.
- 7) Something to write notes on.
- 8) Other: like maybe small change, phone numbers, decorative magnets, candy or anything else that kids keep in their lockers.

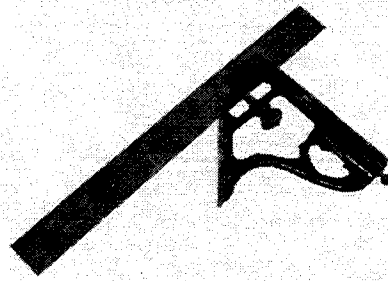
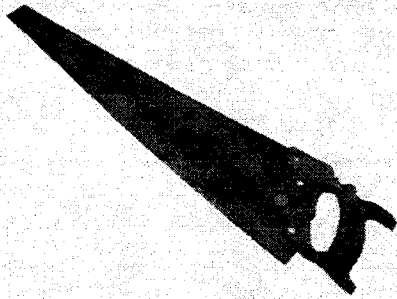
IMAGINEERING

The design team members use their imaginations to come up with a number of solutions to the problem. First, the design team comes up with a number of preliminary solutions. Preliminary means “first”.

The process that the design team uses to come up with these preliminary solutions is called

BRAINSTORMING.





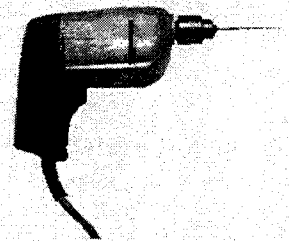
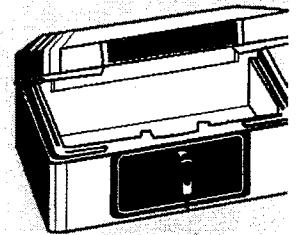
The **PRODUCTION CRITERIA** for the Locker Organizer are the materials and tools available. They are:

Available Materials:

1/8" thick Plexiglas
 thick wood
 hot melt glue
 cement
 canvas
 cardboard
 aluminum foil
 small chain
 two-sided tape
 dry-erase board

1/4" thick Plexiglas
 thin wood
 molded plastic
 cork
 cloth
 foam core
 acrylic (plastic) mirror
 spring clips
 film containers
 screws

sheet metal
 plastic glue
 glass
 ceramic tile
 paper
 rubber
 string
 magnet strips
 Velcro
 nuts and bolts

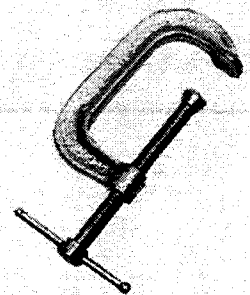
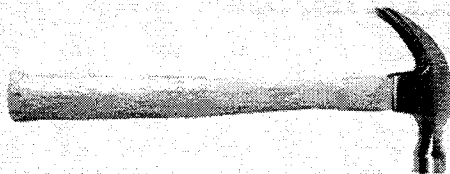
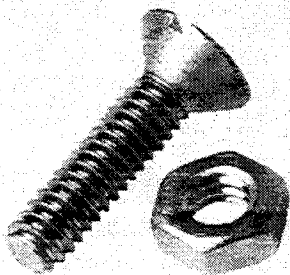


Machines and Tools Available

scroll saw
 welder
 stamping press
 scissors

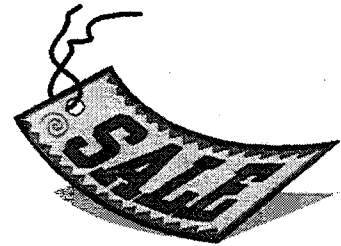
band saw
 molding machines
 hammer
 heat strip machine

hand saw
 sheet metal bender
 pliers
 riveter





MARKET CRITERIA for the Locker Organizer is that it has to look nice. We want people to want to buy our product, so we have to do a good, high quality job on our design. It also must be priced for \$9.99 or less.



ENVIRONMENTAL CRITERIA are that we need to use at least one recycled material in our design. We also must use production methods that don't cause too much pollution.

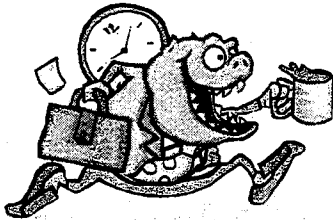
DEVELOPING DESIGN SOLUTIONS



PRODUCT DESIGN = The development of devices or goods that people can use to satisfy a want or need.

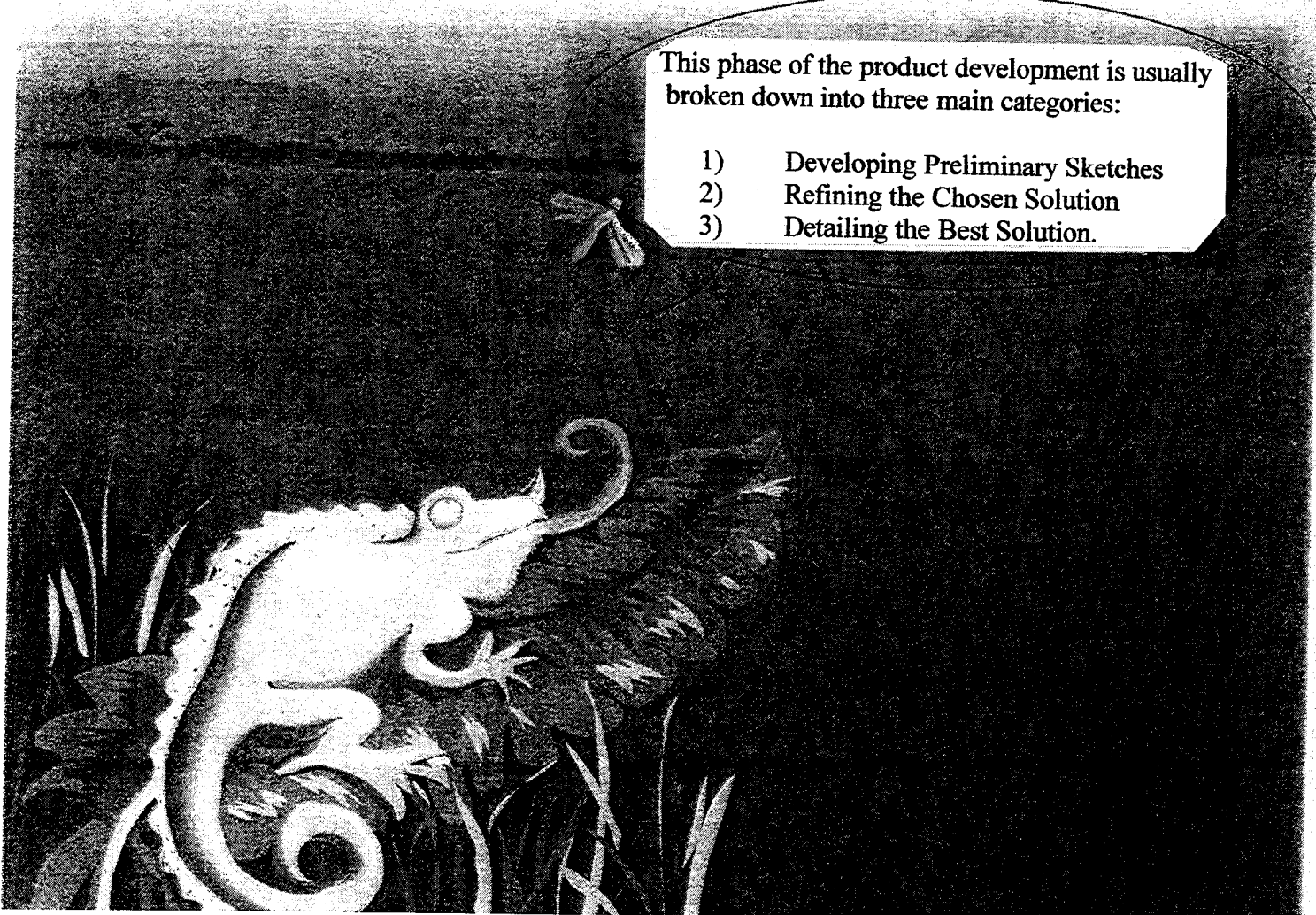
- After you:
- 1) Define the Problem
 - 2) Establish The Criteria
 - 3) Gather Information

It is time to move on to the next step: 4) DEVELOPING DESIGN SOLUTIONS



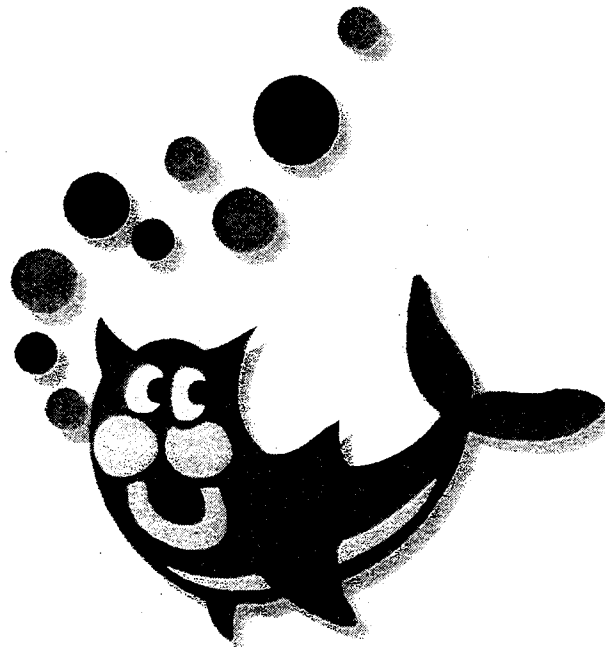
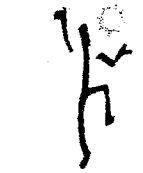
This phase of the product development is usually broken down into three main categories:

- 1) Developing Preliminary Sketches
- 2) Refining the Chosen Solution
- 3) Detailing the Best Solution.



BRAINSTORMING

The design team gathers into a group and lets their creativity run free.



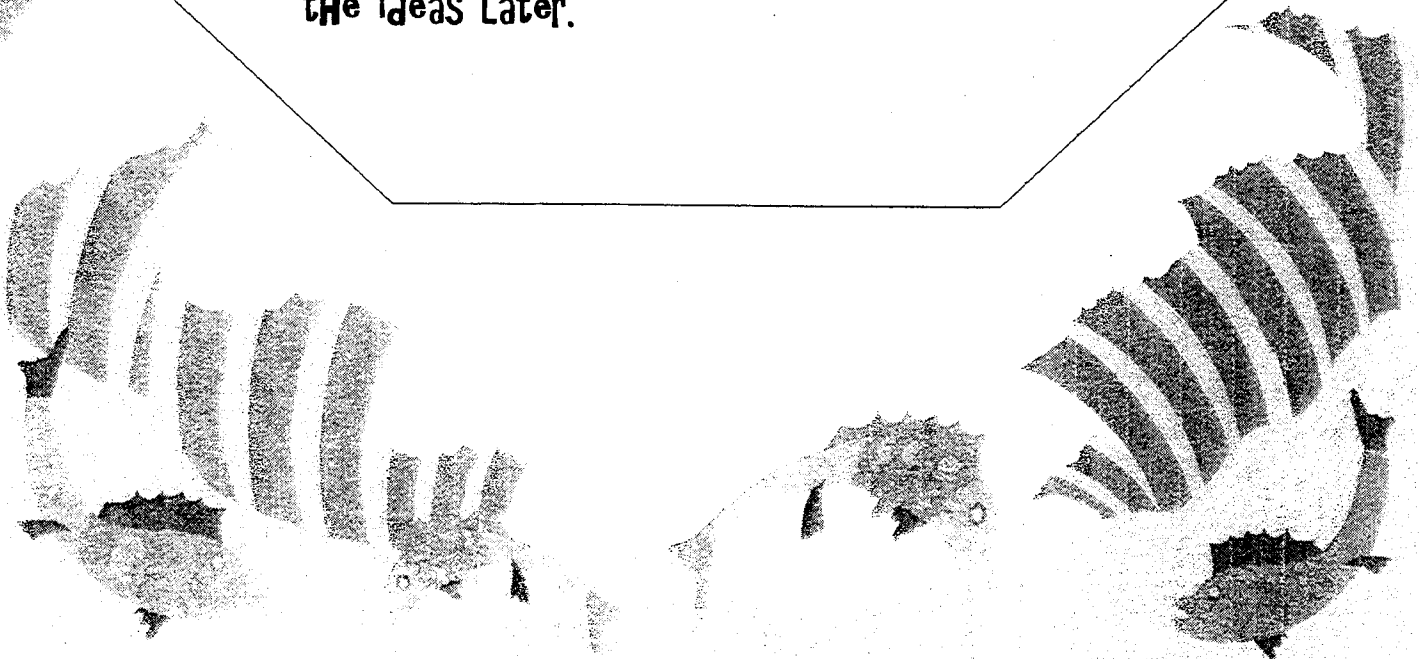
Members of the group call out any ideas that pop into their heads. Brainstorming means "Seeking creative solutions to an identified problem." During a brainstorming session, design team members call out all ideas that come to them. There are no bad ideas during a brainstorming session.



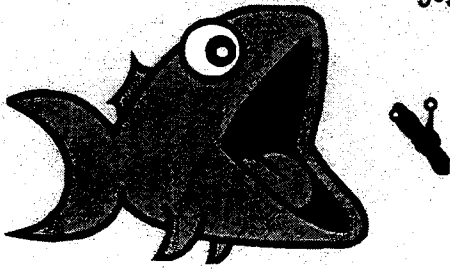


All ideas are good ideas in a brainstorming session. Be as creative as possible. Let your imagination soar.

Try to solve the problem with as many ideas as you can. You can be as wacky as you want. You can refine the ideas later.



For right now, you want to get as many ideas down as you can. Do not worry if they are bad ideas or not - because in a brainstorming session, there are no bad ideas.



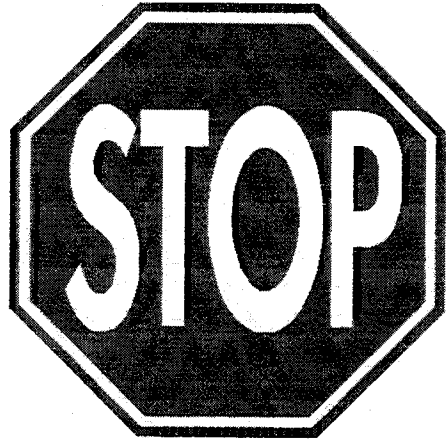
AS LONG AS YOUR IDEAS ARE FOCUSED ON SOLVING THE PROBLEM, THEY CAN BE AS UNUSUAL AS YOUR IMAGINATION WILL ALLOW. REMEMBER TO KEEP IN MIND THE CRITERIA AS IT WAS STATED.



Tips for good Brainstorming:

- **All ideas are good ideas. Even wacky or really goofy ideas can be refined later.**
- **Don't react or criticize anyone's ideas. This can lower creativity and make people not want to give ideas.**





Get your **BRAINSTORMING** sheets
from your **DESIGN PORTFOLIO** and
LET YOUR CREATIVITY
SOAR!



Brainstorming Work Sheet

Name _____ **Date** _____ **Hour** _____

Directions: Record all of your BRAINSTORMING ideas here.

Use as many sheets of paper as you need.

File ALL OF YOUR BRAINSTORMING IDEAS IN YOUR student portfolio.

Brainstorm now. Try to think of as many ideas as you can to solve the problem statement. Write your ideas below. You can sketch your ideas if that helps. Write little notes on the sketches so you will remember what your idea is later. Think of ideas that solve the problem statement and meet the criteria. The functional criteria are what the device must do, and the technological criteria are how the device is made.

Brainstorming Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your BRAINSTORMING ideas here.

Use as many sheets of paper as you need.

File ALL OF YOUR BRAINSTORMING IDEAS IN YOUR student
portfolio.

Brainstorming Work Sheet

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portfolio.

Brainstorming Work Sheet

Name _____ Date _____ Hour _____

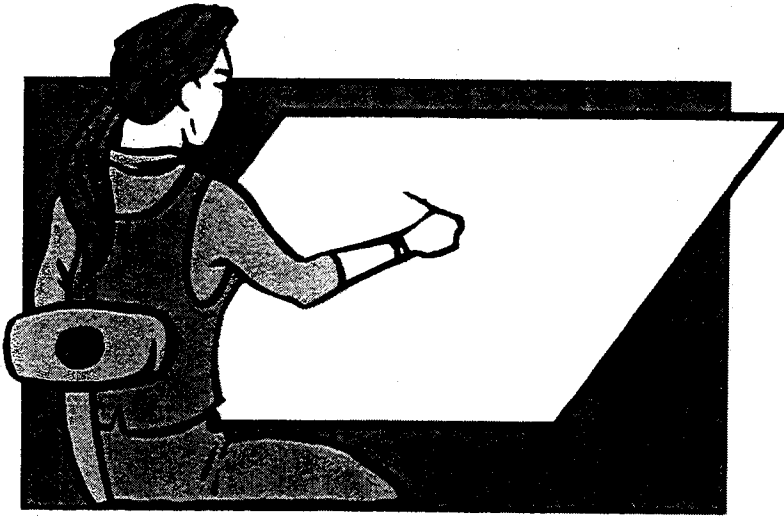
Directions: Record all of your BRAINSTORMING ideas here.

Use as many sheets of paper as you need.

File ALL OF YOUR BRAINSTORMING IDEAS IN YOUR student portfolio.

ROUGH SKETCHING

Draw Sketches of your ideas. The sketches are called “Rough Sketches” because the ideas are still in the unrefined state.



As you make rough sketches of your ideas, you
are making a
LIBRARY OF IDEAS



After your rough sketches are made, the next step is called
Refining the Ideas.



Get your ROUGH SKETCH
sheets from your DESIGN
PORTFOLIOS. Rough Sketch
some of your BRAINSTORMING
IDEAS.



Rough Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your ROUGH SKETCH ideas here. Use as many sheets of paper as you need.

File ALL of your ROUGH SKETCHES in your student portfolio.

Rough Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your ROUGH SKETCH ideas here. Use as many sheets of paper as you need.

File ALL of your ROUGH SKETCHES in your student portfolio.

Rough Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your ROUGH SKETCH ideas here. Use as many sheets of paper as you need.

File ALL of your ROUGH SKETCHES in your student portfolio.

Rough Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your ROUGH SKETCH ideas here. Use as many sheets of paper as you need.

File ALL of your ROUGH SKETCHES in your student portfolio.

REFINING THE IDEAS



Take your rough sketches and select the most practical ones. Pick out the ones that seem to be the best ideas to solve the design problem. Work on these rough sketches that you like to make them better. This is called Refining. Make the sizes and proportions seem better. You can add features (parts) or get rid of ones you don't like.

A Refined Sketch is a Rough Sketch that you made better.

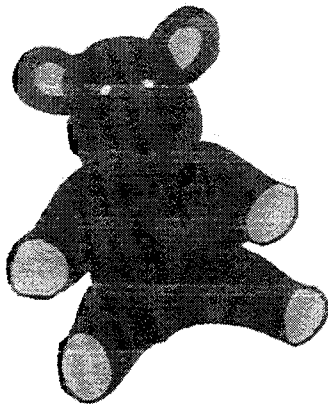


Not all of your rough sketches have to become refined sketches. You can drop any ideas that you think are not worth following up on. Spend your time now on the ideas that you think are best.





Get your REFINED SKETCH
sheets from your DESIGN
PORTFOLIOS. Refine **AT**
LEAST 2 of your rough
sketches.



Refined Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your REFINED SKETCH ideas here.

Use as many sheets of paper as you need.

File ALL of your REFINED SKETCHES in your student portfolio.

Refined Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your REFINED SKETCH ideas here.

Use as many sheets of paper as you need.

File ALL of your REFINED SKETCHES in your student portfolio.

Refined Sketch Work Sheet

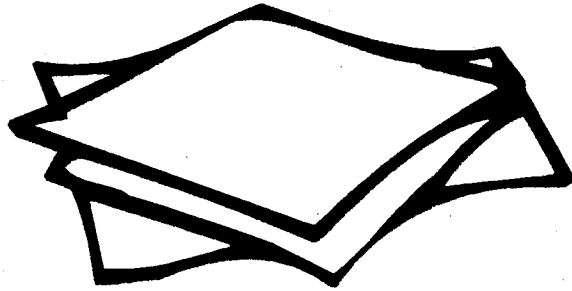
Name _____ Date _____ Hour _____

Directions: Record all of your REFINED SKETCH ideas here.

Use as many sheets of paper as you need.

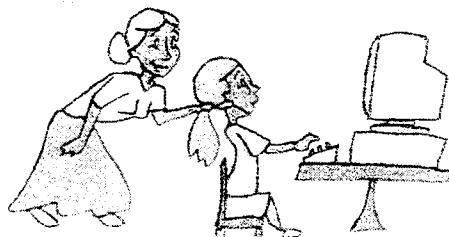
File ALL of your REFINED SKETCHES in your student portfolio.

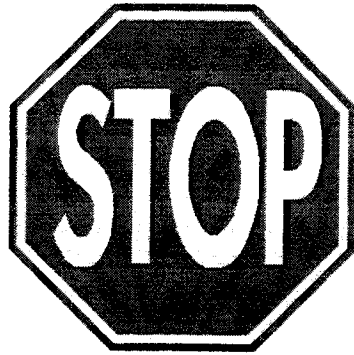
DETAILED SKETCH



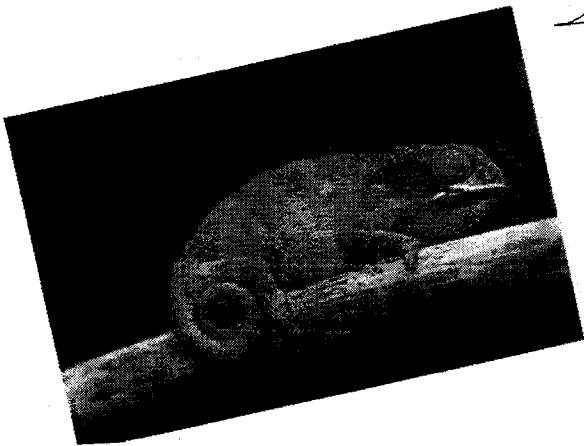
The next step in the design process, after producing the rough sketches and the refined sketches, is to produce Detailed Sketches.

The rough sketches and the refined sketches give you a good idea of what your device will look like. Now you need to figure out where you will make your cuts in the material, where you will make the holes, grooves, lines or any other features your product will have.





Get your DETAILED SKETCH
sheet from your DESIGN
PORTFOLIOS. **DETAIL
YOUR FAVORITE
REFINED SKETCH.**



Detailed Sketch Work Sheet

Name _____ Date _____ Hour _____

Directions: Record all of your DETAILED SKETCH ideas here.

Use as many sheets of paper as you need.

File ALL of your DETAILED SKETCHES in your student portfolio.

Detailed Sketch Work Sheet

Name _____ Date _____ Hour _____

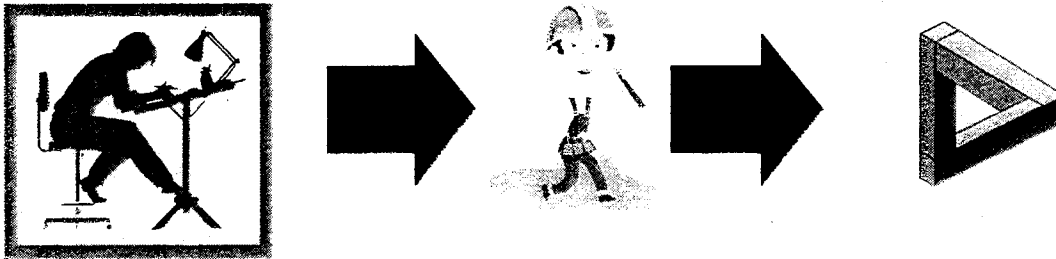
Directions: Record all of your DETAILED SKETCH ideas here.

Use as many sheets of paper as you need.

File ALL of your DETAILED SKETCHES in your student portfolio.

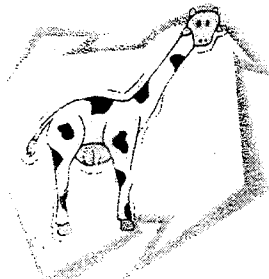
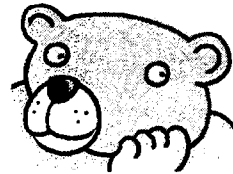
MODELING

The designer's favorite idea is now taken from being an idea on paper, the Detailed Sketch, to being a three-dimensional item called a Mock-Up.



MAKING OF THE MOCK-UP

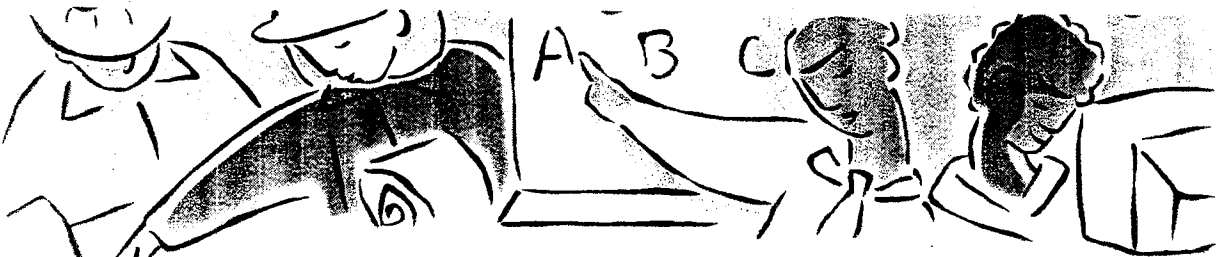
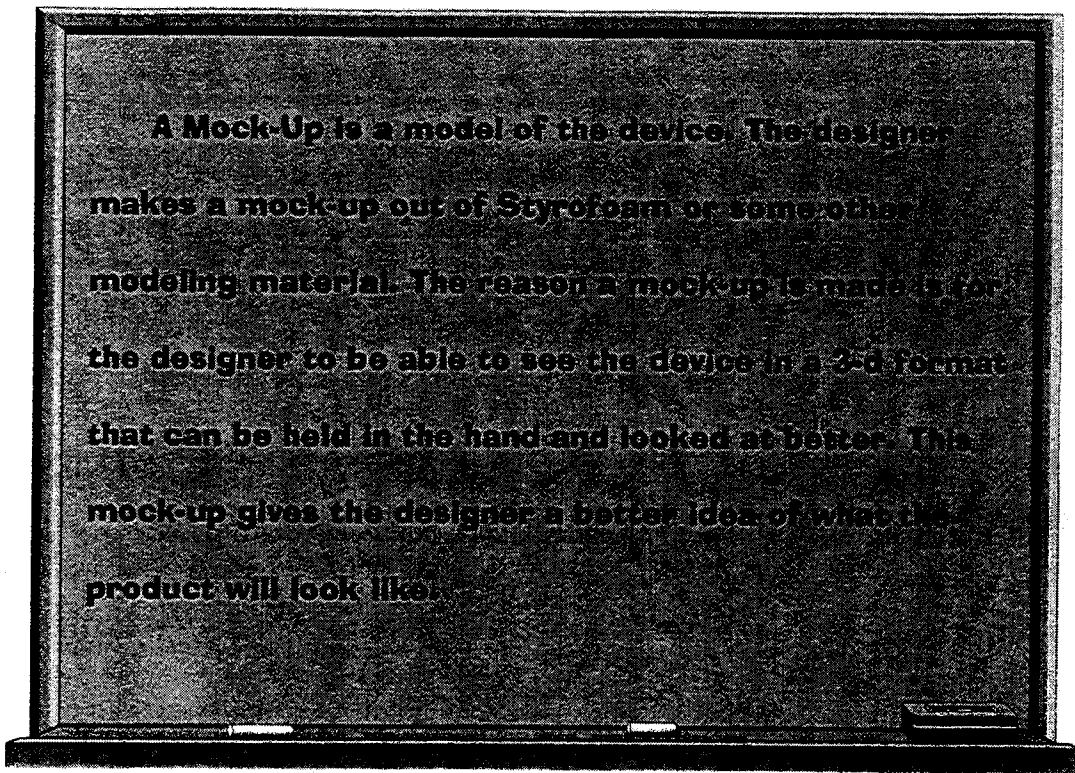
A mock-up does not have to be an exact replica of the final product. The mock-up should, however, be a close resemblance of what the final product will look like.



For this reason, you will want to do a good job when you made your mock-up.



The mock-up model is made so the designers will get a better understanding of what the final product will look like.

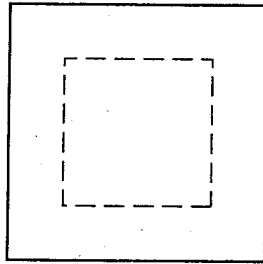


Use your detailed sketch to make your mock-up. You will be using the foam provided in class. You may cut, punch holes, and glue the foam so that the mock-up matches your detailed sketch. You will present your model to the teacher for your final grade.

**NOW YOU ARE
READY TO MAKE
YOUR MOCK-UP!**



Appendix D



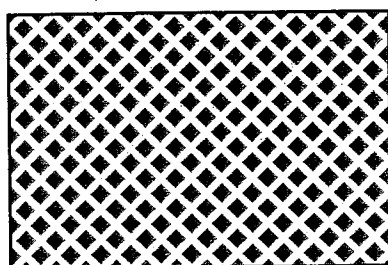
(Kostelnick & Roberts, 1998, p. 36)

Appendix E

Cream Teas
Computer Aided Design

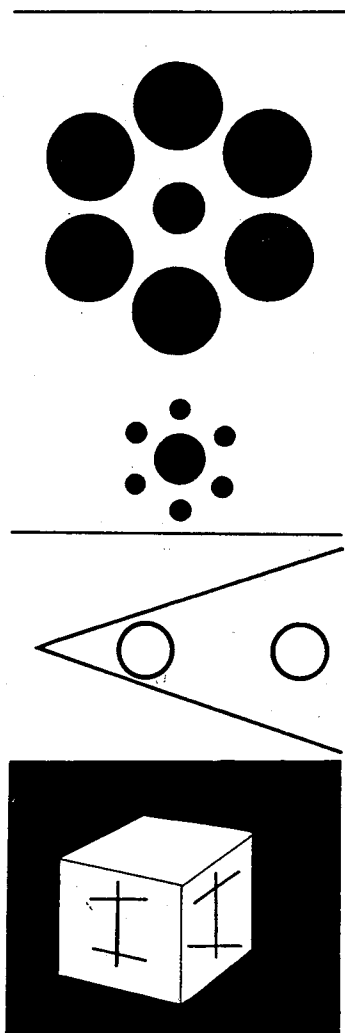
Cream Teas
Computer Aided Design

Appendix F

Monotonous pattern

(Kostelnick & Roberts, 1998, p. 49)

Appendix G



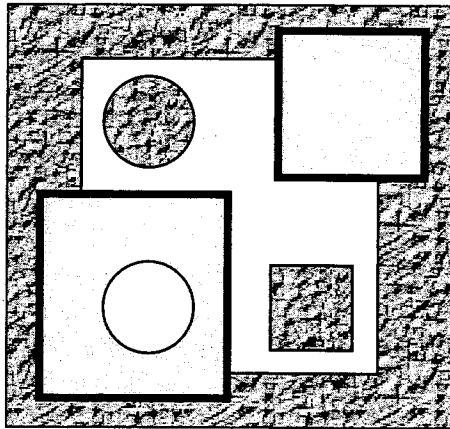
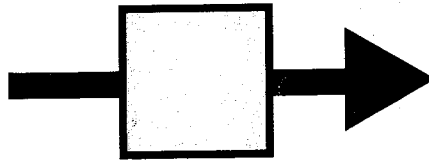
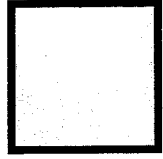
(Kepes, 1944, p. 17)

Appendix H



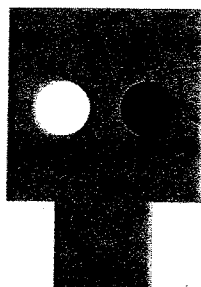
(Kepes, 1944, p. 45)

Appendix I



(Kostelnick & Roberts, 1998, p. 52)

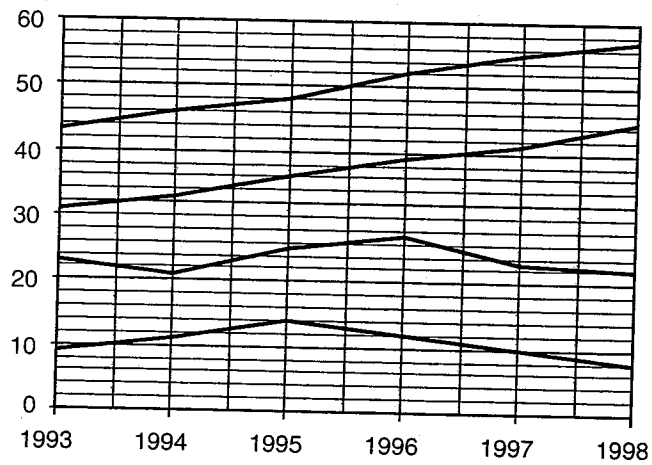
Appendix J



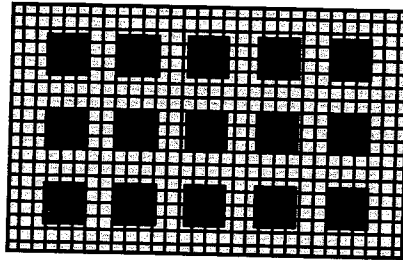
(Kostelnick & Roberts, 1998, p. 54)

Appendix K

A noisy data display



A noisy picture



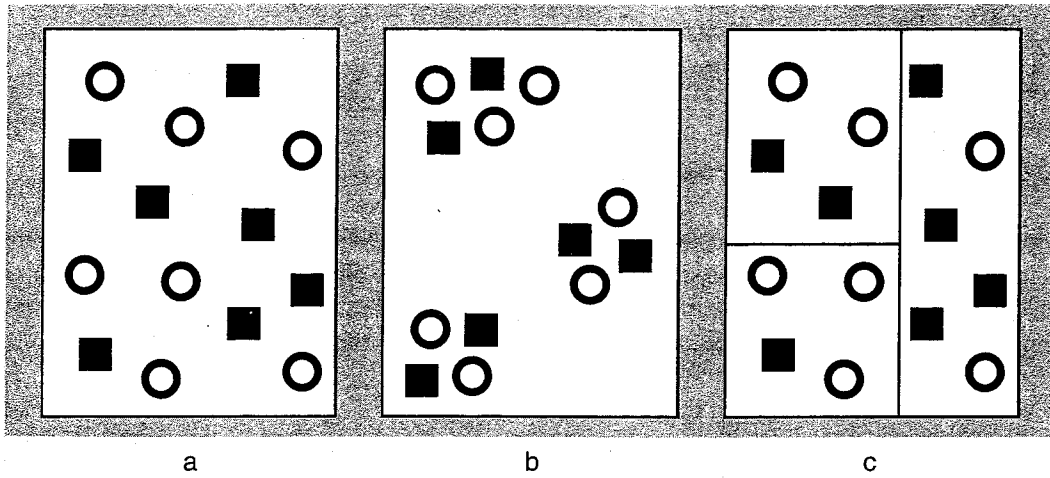
(Kostelnick & Roberts, 1998, p. 60)

This is a noisy typeface.

This is a noisy typeface.

(Kostelnick & Roberts, 1998, p. 58)

Appendix L



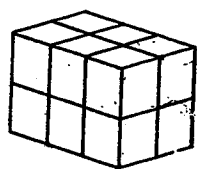
(Kostelnick & Roberts, 1998, p. 61)

Appendix M

1. The Tupolev TU-144 was first seen by the Western world at the Paris Air Show in 1971.
 2. The Tu-144 was demonstrated during the show in 1973.
 3. The TU-144 met with disaster during the demonstration.
 4. It crashed, killing its crew of six and several people on the ground.
-
5. The Western World first saw the Tupolev TU-144 at the Paris Air Show in 1971.
 6. IN 1973, the Show featured a demonstration of the Tu-144.
 7. The demonstration of the TU-144 met with disaster.
 8. When the TU-144 crashed, its crew of sis and several people on the ground were killed.

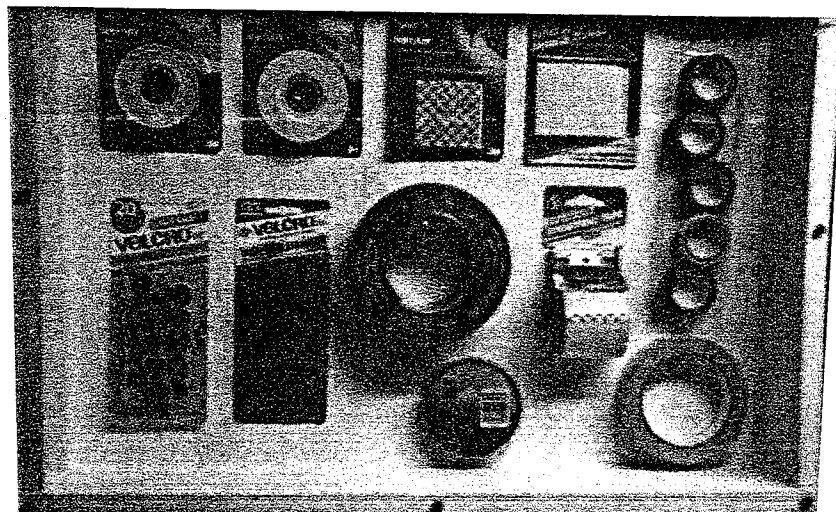
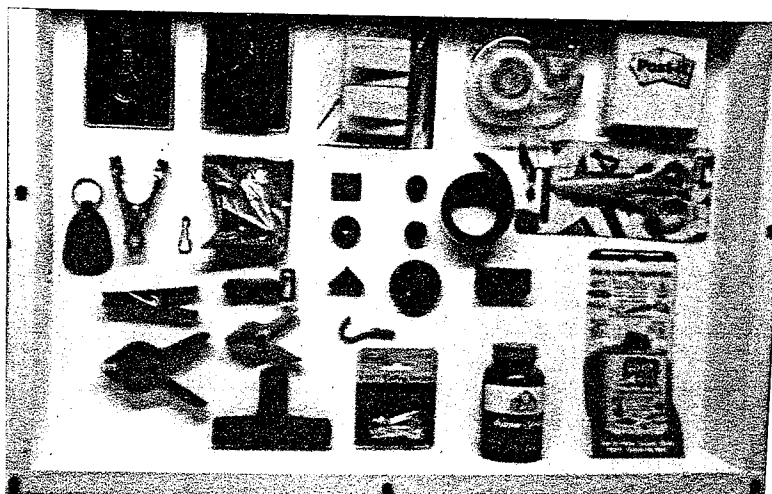
(Faigley, & Witte, 1983, p. 60)

Appendix N



(Lappan, 1984, p. 618)

Appendix O



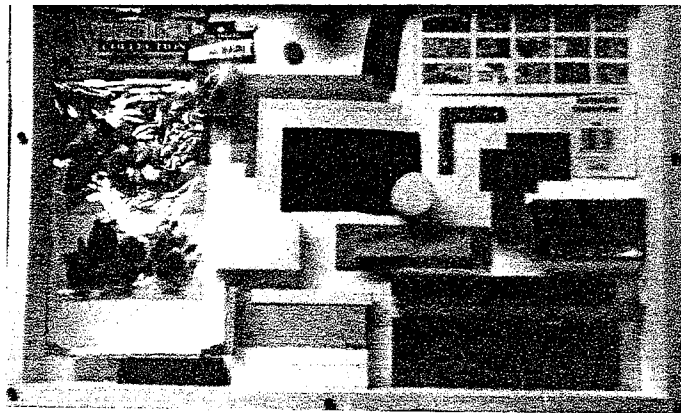
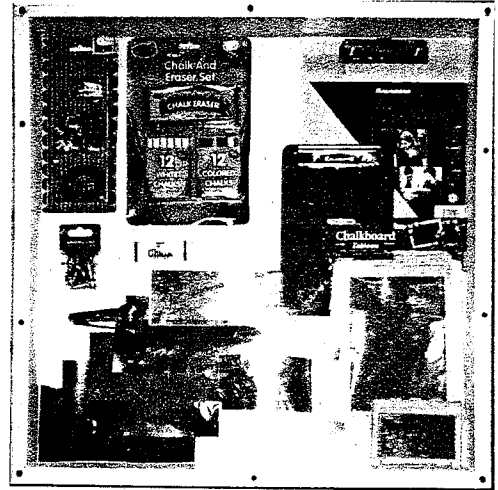


Table 7

Composite Student Scores

Student	Control Group							Cumulative
	1	2	3	4	5	6	7	
1	4	2	4	4	8	3	8	33
2	5	2	3	4	8	3	8	33
3	5	2	4	5	7	3	7	33
4	5	2	2	4	8	3	8	32
5	5	2	4	5	6	3	6	31
6	5	2	5	5	6	2	6	31
7	5	2	1	5	6	3	6	29
8	5	2	5	5	4	2	5	24
9	4	1	1	2	4	2	4	22
10	5	2	4	2	4	2	5	21
11	4	1	4	2	4	2	4	21
12	5	1	4	2	3	2	3	20
13	5	1	3	2	3	2	3	20
14	5	1	2	2	3	2	3	19
15	5	1	3	2	3	2	3	18
16	4	1	3	2	3	2	3	18
17	4	1	0	2	3	2	3	18

18	4	1	2	2	4	2	4	17
19	4	1	0	2	3	2	3	17
20	5	0	3	2	2	1	3	13
21	4	0	2	1	2	1	2	13
22	4	0	2	1	2	1	2	12
23	5	0	0	1	2	1	2	11
24	2	0	2	1	2	1	2	10
25	4	0	-	1	2	1	2	10
26	4	0	-	1	2	1	2	10
27	4	0	-	1	2	1	2	10
28	0	0	-	1	2	1	2	6

Treatment Group

Student	1	2	3	4	5	6	7	Cumulative
1	5	2	1	4	8	3	8	31
2	5	2	2	4	8	3	7	31
3	3	2	2	4	8	3	8	30
4	5	2	0	4	8	3	8	30
5	4	2	0	4	8	3	8	29
6	5	2	4	3	6	3	6	29
7	4	2	5	3	6	3	6	29
8	5	2	3	3	6	3	6	28
9	4	2	3	3	6	3	6	27

10	5	2	4	3	6	3	6	27
11	5	1	3	3	6	3	5	25
12	5	1	4	3	5	2	5	25
13	5	1	4	3	5	2	5	24
14	3	1	3	3	5	3	5	23
15	2	1	3	3	4	3	5	22
16	4	1	5	2	5	2	4	22
17	4	1	5	2	5	2	4	22
18	2	1	5	2	4	2	4	20
19	4	1	5	2	4	2	4	20
20	5	1	3	2	4	2	4	20
21	5	1	3	2	4	2	3	20
22	5	1	4	2	3	2	3	20
23	5	1	4	2	3	2	3	20
24	5	1	4	2	3	2	3	20
25	5	1	4	2	3	2	3	20
26	4	1	4	2	3	2	4	19
27	5	1	2	2	3	2	3	19
28	5	1	3	2	4	1	3	19
29	3	0	5	3	3	2	4	18
30	5	2	2	2	3	1	3	18
31	0	0	4	3	4	2	4	17
32	5	1	2	2	3	1	3	17

33	1	0	3	3	4	2	4	16
34	4	1	0	1	2	1	2	11
35	5	-	-	1	2	1	2	11
36	0	-	-	1	2	1	1	5
