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MASTER OF FINE ARTS

Development of a Series of Experiences to Help Students Evaluate their Aptitudes for
the Study and Practice of Industrial Design

By

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Chapter 1

INTRODUCTION

The field of industrial design appears interesting to many students who are deciding on a career and course of study in college. The “play” aspect involved in the creative process and of designing “cool” artifacts is especially intriguing. Many students make their decisions to pursue industrial design based on what they perceive the field to be and not what it really entails. They make the decision to study industrial design on a misconception without considering their aptitudes for the other aspects involved in industrial design. They don’t think about the aptitudes that may be needed for the study of industrial design, finding placement and satisfaction in the industry, and ultimately, being successful in the profession.

There are a number of reasons for my interest in this research. First is my own personal experience with the search for, discovery of, and education in industrial design. When I was searching for a career choice in my early college days I knew what my aptitudes were. I loved to draw, especially mechanisms and machines, future vehicles and cars, and people. I had a mechanical aptitude and loved to fix things, make things and discover how things worked. I was always inventing things to make life easier, but not on a serious level. I struggled with algebra and I loved geometry in high school and I breezed through my shop classes. I never built the standard projects but was always asking permission to build something I considered more useful. I knew what my aptitudes were. My struggle was finding the profession where I could apply what I was good at and had passion for. I studied art because I knew I liked to draw but I found art to be lacking and unsatisfying. I studied graphic design and found that it
neglected my mechanical, hands on, dimensional needs. I studied engineering and found it too technical (a class in thermodynamics did me in). At last, I studied business, reasoning that no matter what I did in life, a degree in business would be helpful. I struggled with the basic accounting course. The day I discovered industrial design I knew that it was for me. I walked into a room of students working on a model of a full-size energy efficient kitchen for Armco steel. There were sketches and drawings all over the walls, mechanisms all around and a big model of a kitchen of the future. I knew I had found what I had been looking for, and for 20 years I have found great satisfaction in my career. I found a career that best fit my aptitudes.

After deciding to study industrial design I had an experience that reinforced my curiosity about aptitudes. In my sophomore class of industrial design there were 20 or so students. I believe they were there because of the “fun factor.” The next year there were five students, and in the end, I was the only one to graduate in my class. I remember the pressure to produce a lot of ideas in a very short period of time. In the critiques I would show 20 or 30 ideas when some of the other students could only come up with 5 or 6. The “fun factor” quickly disappeared under the pressure of lots of good, innovative ideas. In a casual conversation with my professor one afternoon he said something that stuck with me all these years. He thought he could ask a series of questions about the student and know if he or she would do well in the ID program. I was interested in those questions and we started to talk about them. We were interrupted so the list was cut short. The few questions I remember were: How did you do in geometry as opposed to algebra? How did you like your shop class? Did you
ever doodle in the margins of your math homework? This was my experience in school 20 years ago.

Now I am looking at the situation from the other side, that of a teacher. In my short experience with teaching, I have seen the opposite of my college experiences. Instead of students discovering their aptitudes and then choosing a field of study, I see students choosing a field of study and then trying to discover their aptitudes. Our curriculum at RIT, like many schools, teaches fundamental skills in the sophomore year, and the students really don't experience any design process until their junior year. Some find they don't have the aptitudes for it but have invested so much time and money they feel stuck.

This leads me to my last reason for this research. As a student attending school for the purpose of earning my credentials to teach, I want to develop a method to help students determine early in their education if they “have what it takes” to succeed in industrial design.

I think all teachers have had the experience of students coming into their program who learn quickly, can apply their knowledge, are focused, passionate, and enjoy the work. They have also seen the opposite.

What I propose to do is to discover and define the aptitudes that are desirable for industrial designers, and explore ways to allow the students to experience and realize what these aptitudes are in order to help the students self-evaluate their “fit” for the study of industrial design.
Chapter 2

PROCESS

What is an Aptitude?

According to Webster’s Unabridged Dictionary an aptitude is “a capacity or ability innate or acquired, a talent for learning, or a special fitness. Synonyms are: predilection, proclivity, bent, gift, or faculty.”\(^1\) Another definition of aptitudes is, “Aptitudes are psychological constructs about individual differences in learning or performance in specified situations.”\(^2\) In his book, *Aptitude, Learning, and Instruction*, Edward Hoffman says,

Aptitudes are natural talents, special abilities for doing, or learning to do, certain kinds of things easily and quickly. Manual dexterity, musical ability, spatial visualization, and memory for numbers are examples of such aptitudes. These and many other aptitudes can be measured. These measured traits are highly stable over long-term periods...every occupation -- whether it is engineering, medicine, law or management -- uses certain aptitudes. The work you are most likely to enjoy and be successful in is work that uses your aptitudes. For example, if you are an engineer, but possess aptitudes not used in engineering, your work might seem unrewarding. If you lack the engineer’s aptitudes, your work may be difficult or unpleasant.\(^3\)

I have observed that aptitude promotes a passion for learning the skills of design.

An aptitude is the potential to learn the skills needed for a specific type of job or career.

One’s aptitudes represent the underlying building blocks one possesses for learning skills quicker and easier. It is important to keep in mind that aptitude is the potential to

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1 Webster’s Unabridged Dictionary, (New York, Gramercy Books, 1983) p. 75


acquire a skill, and is not the skill itself. The skills that we teach: sketching, rendering, technical drawing, model making, and the use of software, seem to come easier to those that have aptitudes for those skills. It's because, as the dictionary definition says, they have a talent for learning. Otherwise, trying to learn these skills can be a lesson in frustration. Students with high aptitudes still need to be taught the various skills; they just have a better chance of benefiting from the same amount of teaching than do people with lower aptitudes. Aptitudes plus skills is the formula for successful students and professionals.

On the other hand, low aptitude for a skill does not mean that the skill cannot be acquired. While it is widely recognized that most can learn any skill, if they are willing to put their minds to it, it is also widely recognized that some people are simply more apt at learning certain skills than others. It just means that reaching the level of proficiency will probably be more difficult and time-consuming for them than it is for individuals with greater aptitude for that skill. An aptitude does not determine what you know, or even decide what you can learn. All it does is determine how difficult it will be for you to learn.

This concept has been understood for many years, and now brain research is helping us to understand why. A Carnegie Mellon research team found that the amount of brain activation occurring with each test depended on how apt the participant was in that kind of thinking. The research explained that more aptitude was associated with less activation, just as more aptitude at something physical, like swimming, results in less muscle activity to perform a given task.
Individuals with better verbal skills had less activation in brain activity when they used the verbal strategy. Similarly, individuals with better visual-spatial skills had less activation in the left parietal cortex when they used the visual-spatial strategy.  

Brain activity is at its highest when the brain is in a stressed state. If we do tasks that are compatible with our aptitudes, we experience a comfortable level of brain activity. When we do tasks that are not compatible our brain activity is greater. This may be the cause of the frustration and difficulty. I have had students in technical drawing and concept design sketching express a very high degree of frustration with assignments that others seem to have no problem with.

B. Eugene Griessman in his audiocassette, *Path to High Achievement⁵*, has a section on discovering your specialty. He likens aptitude to a resident frequency. If you tap a tuning fork next to a piano the “C” string will resonate. When we come in contact with things that are compatible with our aptitudes they seem to resonate within us.

**What are the Industrial Design Aptitudes?**

What are the aptitudes that a potential industrial designer should have to make a learning experience and professional career rewarding? How does one discover these aptitudes and how does one use the information responsibly?

I developed my own list, but wanted to verify what I felt were the core aptitudes with other designers. I surveyed twenty-five designers to get their input on what these

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aptitudes might be. I selected designers in industry and education, in corporate and consulting, in transportation, exhibit, and product design. I sent each of the designers e-mail (fig. 1) or talked to them personally and asked them to brainstorm the aptitudes they thought would be most valuable to a potential industrial designer. I also did a review of the literature that talked of the same aptitudes.

The input was fairly consistent regarding aptitudes a designer should have, with a few surprises. As I studied the information I saw that there seemed to be some natural groupings based on how people think. I outlined all the aptitudes and then tried to refine them down into simpler categories. What resulted was interesting. I understood the aptitudes, but hadn’t recognized how they related to each other. There were also aptitudes that I had a hard time categorizing.

I had a number of comments such as: "will try new approaches, ability to create a number of solutions to the same problem, ability to make new combinations, naturally innovative, a problem solver." I combined these inputs under the area of creative thinking. Responses like: "good at geometry, visual thinker, curious about how things

To: <samuel.swayze@kodak.com>
cc: 
Subject: Aptitude research

Sam, I want to thank you in advance for your help.

According to Webster's Dictionary an aptitude is "a capacity or ability innate or acquired, a talent for learning, or a special fitness." Synonyms include: predilection, proclivity, bent, gift, or faculty.

Edward Hoffman says "Aptitudes are natural talents, special abilities for doing, or learning to do, certain kinds of things easily and quickly. Manual dexterity, musical ability, spatial visualization, and memory for numbers are examples of such aptitudes. He goes on to say, "every occupation—whether it is engineering, medicine, law or management—uses certain aptitudes. The work you are most likely to enjoy and be successful in is work that uses your aptitudes. For example, if you are an engineer (or designer) but possess aptitudes not used in engineering (or design), your work might seem unrewarding. If you lack the engineer's (or designer's) aptitudes, your work may be difficult or unpleasant."

What are the aptitudes that make a potentially successful designer?

If you could brainstorm a list of aptitudes you think are important and return it to me I would appreciate it very much. -Paul

Fig. 1. Sample aptitude survey
work, mechanical ability, and attention to detail,” I listed under visual thinking. The unique aptitudes that were hard to categorize went like this: “ability to accept criticism, comfortable with risk, adaptive to change, is able to handle frustration, feels what’s right, is confident.” At first I tried to fit these items into creative thinking, but it didn’t seem right. As a part of my research I read Michael Gelb’s book, How to Think Like Leonardo da Vinci. He says, “A designer must have a willingness to embrace ambiguity, paradox and uncertainty.”6 I have read a number of articles about tolerance for ambiguity, change and paradox, and decided it is an aptitude of a designer. I call this form of thinking “flexible thinking.”

Thus, the aptitudes were defined under three main categories: visual thinking, creative thinking, and flexible thinking. The foundations of aptitudes are based in ways of thinking. Thinking is how we receive information, how we process information, and how we use that information. Aptitudes grow out of these ways of thinking. The aptitudes under each way of thinking make a very long list. I am focusing on the aptitudes that came up in the survey to make the research manageable. I picked aptitudes that were specific to the largest demographic of mainstream industrial designers.

Interestingly, the most often mentioned aptitude from the survey was: “curious about how things work.” The survey also included things that didn’t fit the area of aptitudes. These responses fell under the headings of attitudes, knowledge, and skills. The list is categorized into visual, creative and flexible thinking (fig. 2). To check my

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assumptions about the three areas of thinking and how the aptitudes fit in each area I developed a mind map (fig. 3) of the thinking styles and all the information I could

<table>
<thead>
<tr>
<th>Creative thinking</th>
<th>VT—Sense of style</th>
<th>VT—Systems thinking or the view of the whole</th>
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<tr>
<td>CT—Creative</td>
<td>VT—A sense of structure</td>
<td>VT—Passion for form</td>
</tr>
<tr>
<td>CT—Will to try new approaches and experiments</td>
<td>VT—A sense of assembly</td>
<td>VT—Visual thinking</td>
</tr>
<tr>
<td>CT—Creative</td>
<td>VT—A sense of mechanics</td>
<td>VT—Loves to take things apart</td>
</tr>
<tr>
<td>CT—Creative Person</td>
<td>VT—A sense of style</td>
<td>VT—Loves to build things</td>
</tr>
<tr>
<td>CT—Ability to create multiple solutions to the same problem</td>
<td>VT—A sense of purpose</td>
<td>VT—Enjoy solving problems or puzzles</td>
</tr>
<tr>
<td>CT—Creative/inventive</td>
<td>VT—A sense of reason and logic</td>
<td>VT—Like to draw or doodle</td>
</tr>
<tr>
<td>CT—Playful/sense of humor</td>
<td>VT—A sense of accuracy</td>
<td>VT—Have a keen eye for detail</td>
</tr>
<tr>
<td>CT—Willing to learn new things</td>
<td>VT—bloody picky’</td>
<td>VT—Have a good sense of parts to the whole</td>
</tr>
<tr>
<td>CT—Innovative, inventive, creative</td>
<td>VT—Likes working with his hands</td>
<td>VT—Is mechanically adept</td>
</tr>
<tr>
<td>CT—Open-minded</td>
<td>VT—Likes to doodle</td>
<td>Flexible thinking</td>
</tr>
<tr>
<td>CT—Asks the right questions</td>
<td>VT—Understands and does well in geometry</td>
<td>FT—Adaptable to change</td>
</tr>
<tr>
<td>CT—Problem solver</td>
<td>VT—Visual thinker</td>
<td>FT—Self-confidence</td>
</tr>
<tr>
<td>CT—Never stops thinking</td>
<td>VT—Sensitivity to form</td>
<td>FT—Must be acceptable of criticism</td>
</tr>
<tr>
<td>CT—Ability to relate to the ideas of others</td>
<td>VT—Curious</td>
<td>FT—Able to handle frustration when designs are</td>
</tr>
<tr>
<td>CT—Ability to make new combinations, Creative</td>
<td>VT—Understanding of how thing work</td>
<td>rejected or projects are suddenly changed</td>
</tr>
<tr>
<td>CT—Demonstration, desire to test, experiment, and make mistakes</td>
<td>VT—Work with your hands, building stuff</td>
<td>FT—Tolerance for ambiguity</td>
</tr>
<tr>
<td>CT—The refinement of the ability to see</td>
<td>VT—Relative success in Geometry</td>
<td>FT—Wants to make things better.</td>
</tr>
<tr>
<td>CT—Inquisitive/curious</td>
<td>VT—Strong aesthetic sensitivity and artistic</td>
<td>FT—High self esteem, confident, not sensitive to</td>
</tr>
<tr>
<td>CT—Curiosity</td>
<td>VT—Likes/understands mechanisms, mechanically minded</td>
<td>design criticism</td>
</tr>
<tr>
<td>Visual thinking</td>
<td>VT—Sees and feels 3D from 2D stimulus</td>
<td>FT—Comfortable with risk</td>
</tr>
<tr>
<td>VT—Eye for detail</td>
<td>VT—Process oriented: applies a level of order and discipline to design approach</td>
<td>FT—Self-critical</td>
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<td>VT—Sense of balance and proportion</td>
<td>VT—Ability to visualize form in 3D from 2D images</td>
<td>FT—Ability to accept criticism</td>
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<td>VT—Must be practical</td>
<td>VT—Hand/Eye coordination</td>
<td>FT—Go with the flow, not resistant to change</td>
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<td>VT—Perseverance to stay with a project from start to finish</td>
<td>VT—Natural drawing talent</td>
<td>FT—Willingness to embrace ambiguity, paradox, and</td>
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<tr>
<td>VT—Understanding and curiosity of how things work</td>
<td>VT—Natural curiosity, Desire to know how thing work</td>
<td>uncertainty.</td>
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<tr>
<td>VT—Ability to visualize form</td>
<td>VT—Color and graphic sensitivity</td>
<td>FT—Confidence in self</td>
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<td></td>
<td>VT—Really looks at things/Aware of surroundings</td>
<td>FT—Willingness to know that tomorrow brings a bigger</td>
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<tr>
<td></td>
<td>VT—Mental visualize</td>
<td>challenge</td>
</tr>
<tr>
<td></td>
<td>VT—Think in 3D</td>
<td>FT—Big ego/ self confident</td>
</tr>
<tr>
<td></td>
<td>VT—Express ideas in 2D</td>
<td>FT—Willingness to know that tomorrow brings a bigger</td>
</tr>
<tr>
<td></td>
<td>VT—Keen perception of detail</td>
<td>challenge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FT—Thick skinned</td>
</tr>
</tbody>
</table>

Fig. 2. Comprehensive aptitude list

outline about each area. Then I plugged in the aptitudes to see if we had a fit for all of them. All the aptitudes seemed to fit in the three categories, so I was satisfied with the conclusion of thinking styles.
To further test the validity of my conclusions about the industrial designers' fundamental thinking styles, I tried to see if the style could stand on its own. I found there were crossover aptitudes that seem to tie the three together (fig. 4).
For example, tolerance for ambiguity seems to be a creative thinking aptitude as well as a flexible thinking aptitude. It is a crossover point, yet it also stands on its own. There are people with a tolerance for ambiguity that are not creative and visa versa. Intuition is thought of as a creative thought process, yet many people rely on their intuition to make decisions that are not creative. There are also overlaps on the visual side. Drawing is recognized as a visual thinking skill but plays a strong role in creativity. Yet there are people who are very creative who are not visual, and visa versa. Curiosity is a great aptitude for a creative person, but is also a visual thinking aptitude. Some designers compensate for their lack of aptitude in certain areas, but that areas seem to be a frustration to them in their work. The best scenario is a student with all three thinking styles.
Visual Thinking

What is visual thinking? The definition of thinking is how we receive, process, and use information. At the simplest level, visual thinking is when the information we receive, process and use comes to us in the form of images. The simplicity should not be underrated. "The words of language, as they are written and spoken, do not seem to play any role in my mechanism of thought,"7 Albert Einstein. It suffices to mention the likes of Einstein as a visual thinker to convince us of the value of visual thinking. The ramifications of thinking in terms of images, not language and numbers, have a broad effect on the information processing. According to Rudolf Arnheim, "Visual thinking calls for the ability to see visual shapes as images of the patterns of forces that underlie our existence - the functioning of minds, of bodies or machines, the structure of societies or ideas."8 In the words of Howard Gardner, visual thinking "incorporates a number of loosely related capacities: The ability to recognize instances of the same element; the ability to transform or to recognize a transformation of one element into another; the capacity to conjure up mental imagery and then to transform that imagery; the capacity to produce a graphic

7 Albert Einstein, (http://stripe.colorado.edu/~judy/einstein/knowledge.html)
likeness of visual information." Visual thinking is very fast, complex and not sequential. As L.K. Silverman notes,

Visual thinkers thrive on complexity, are system thinkers, have high abstract reasoning facility, love difficult problems, have keen visual memory, have a good sense of humour, and are creative and imaginative. Visual thinkers also have better mathematical analysis skills than computational skills, they are better at geometry than algebra, better at physics than chemistry, love music, television and movies, they are daydreamers, and elaborate doodlers.10

Central to the visual thinking style are the capabilities to perceive the visual world accurately, to not only receive visual information but also be able to process the information, manipulate the information, and apply the information.

The capacities or aptitudes I chose to examine under the heading of visual thinking are the ones that the survey pointed out and that I felt were most pertinent to the industrial designer. They are: 3D visualization aptitude, visual language aptitude (sketching, drawing, doodling), mechanical aptitude and, aesthetic aptitude.

3D Visualization Aptitude

Once one is asked to manipulate the form or the object, appreciate how it will be comprehended from another viewing angle, or how it would look (or feel) were it turned around, one enters fully into the spatial [visual] realm, for a manipulation through space has been required. Such tasks of transformation can be demanding, as one is required to "mentally rotate" complex forms through any number of twists and turns.11

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Investigations into the development of spatial [visual] skills led to theories that divide the ability to visualize into retaining images and the ability to transform these images. Each of these areas has subsets. I believe the following to be most relevant to the aptitude of 3D visualization and the industrial designer in descending order according to difficulty:

1. The ability to remember and compare images in your imagination,
2. The ability to orient 3D objects mentally. (e.g. to rotate the object in your mind.)
3. The ability to place oneself in an environment and move about that environment mentally,
4. The ability to mentally deconstruct and manipulate components of a 3D object. (e.g. Manipulations like unfolding a 3D object into a flat pattern, make cross-sections thru an object, or explode an object’s parts in a logical way, to modify and reassemble elements within an object mentally.)

One way of defining visual thinking is to attempt visual tasks. I have developed or adapted some visual thinking assessment tools into a series of experiences that students can have with each of the tasks.

Experiences in 3D visualization aptitude

**Hold and compare images.** This task was to have the students experience and evaluate their ability to remember an image and make comparisons in their mind. The task was to draw a cereal box, then in proportion to the cereal box draw a
macaroni and cheese box, then another box shape item to a series of 6 or 7 items. The same was to be done with cylinders. They were only to use proportion, no other indicators allowed. The students then evaluated each other's work to see if they could recognize the shape by comparison (This acts as a mild critique for the person who has attempted the task to see if others recognize their items). Some students were able to reproduce the items from memory and compare them to other items successfully (fig.7). Some students struggled with remembering and comparing the items. (fig. 8). I noticed an interesting thing in the comparisons. The students who did well on the hold and comparing of images also did better on the representing them in sketches. The ones who did poorly also struggled with the representation. This shows how the two aptitudes, 3D visualization and visual language, are closely associated.

Fig. 5. Boxes in proportion
Fig. 6. Cylinders in proportion

Fig. 7. Successful proportion experience
Mental rotation of images. I have adapted 3 tasks for mental image rotation. The first task is based on a series of test figures constructed by psychologists Lynn Cooper and Roger Shepard.\(^{12}\) There is a set of figures in different rotations. These figures test an individual’s potential for visual thinking, specifically the rotation of objects in our minds. The task is as follows: The first figure set is shown and the student has 5 seconds to determine if the shape is the same or different (fig. 9). If he or she has aptitude for visual thinking one will be able to mentally rotate the shape in his or her mind to match the other shape to see if they are the same or different. The next shape is shown and the student does the same, and continues through all eight comparisons.

In the second test for rotation, the student must examine the object on the left and compare it with the four objects accompanying it on the right in order to identify which is the correct representation in rotation (fig. 10). Again the student must mentally rotate the object in order to solve this type of problem. This test has no time restriction.

The third test is a standard test from technical drawing but has great application in mental rotation. The student is asked to complete the view, top, side, or front. In one instance there are lines missing from the view, and in another the student has to complete the view. The last task in this series is to see if the students can mentally rotate the object to see what it would look like from a different point of view (fig. 12).
Fig. 10. Rotation images 2

Fig. 11. Experience evaluation on mental rotation
Add the lines that are missing to complete the three views.

Draw the views that are missing where they are indicated.

Fig. 12. 3-view experience

Fig. 13. 3-view experience evaluation
Mental Manipulation of images. “If you can imagine a box unfolded, …you have spatial aptitude.”\textsuperscript{13} This task is to see if the student can mentally manipulate a 3D object. The student is given 3 representations of a 3D object (fig. 14) and asked to make a flat pattern of each object. One is to make it with standard pattern conventions, cut on the solid line, and fold on the dotted line. One object is to try and match the proportion and make the pattern so that it requires the least amount of “welds” (folding is easier then gluing). Each student is to bring the flat patterns to class and not try to fold it. In class students exchange patterns and fold each other’s forms. This is mild feedback to the students on whether or not their flat pattern works. In an interesting side to this experiment, I found that the students who had the hardest time with the flat pattern also had a hard time with the folding.

\footnotesize\textsuperscript{13} Mechanical and Spatial aptitude, (New York, Learning Express, 2001) p. 13
Fig. 14. 3D shapes

Fig. 15. Successful pattern experience

Fig. 16. Unsuccessful pattern experience
Visual Language Aptitude

Another aspect in the visual thinking aptitude is the visual thinking language, drawing, sketching or doodling. The designers in my survey mentioned a number of skills such as natural drawing ability, drawing talent, communicates visually, and sketches (this paper uses the term sketching). I placed sketching in both the aptitude column and the skills column. I believe that sketching is a skill that can be taught, and students can learn if they have aptitude for visualizing form. Sketching seems to come more naturally to visual thinkers. The use of sketching, modelling and drawing is taken as evidence of visual thinking. This natural ability comes from a visual thinker's desire to express thoughts and the ability to see things accurately in one's mind. It is the language used to record and communicate ideas, usually to one's self, and at times to others. Sketching is closely tied to our ability to see, think, and imagine.

Although visual thinking can occur primarily in the context of seeing, or only in imagination, or largely with pencil and paper, the expert visual thinker is flexible and utilizes all three kinds of imagery. He finds that seeing, imagining, and drawing are interactive.14

Drawing not only helps to bring vague inner images into focus, it also provides a record of the advancing thought stream. Further, drawing provides functions that the memory cannot. The most brilliant imager cannot compare a number of images, side by side in memory, as one can compare a wall of tacked-up idea sketches.15

Sketching improves our ability to visualize. To represent an object in the form of a sketch one must understand the object more completely. The act of drawing


15 Ibid., p. 10
"has nothing to do with ... technique. It has nothing to do with aesthetics or conception. It has only to do with the act of correct observation."\(^\text{16}\)

There are three kinds of sketching: sketching from observations, sketching from memory and sketching from imagination. They are all interrelated.

Drawing relies on a clear vision. It also requires thought, which, in turn, builds understanding. Drawing cannot be detached from seeing and thinking about the fundamental nature of the subject being represented. The knowledge and understanding gained through drawing from life directly enhances our ability to draw from the imagination. Just as thought can be put into words, ideas can be made visible in a drawing to promote visual thinking and further stimulate the imagination. Once what is seen or imagined is made visible in a drawing, the image takes on a life of its own and communicates graphically.\(^\text{17}\)

Sketches are a tool for aiding in the generation of ideas. Drawing to extend ones thinking is frequently confused with drawing to communicate a well-informed idea.

Graphic ideation precedes graphic communication: graphic ideation helps to develop visual ideas worth communicating. Because thinking flows quickly, graphic ideation is usually freehand, impressionistic and rapid. Because communication to others demands clarity, graphic communication is necessarily more formal, explicit, and time-consuming. Education that stresses graphic communication and fails to consider graphic ideation can unwittingly hamper visual thinking.\(^\text{18}\)

Sketches help to clarify and amplify thinking, particularly where the individual is engaged in the process of solving a problem.

Sketching is the process of making a sketch. A sketch is a rough drawing that represents the chief features of an object. To be more precise, a sketch would accomplish the following: 1) Capture the essence of the

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object, 2) give a simplified version of the object, 3) provide an abstract
graphic description of reality, 4) create a graphic expression with the
minimum of lines, tones, and textures, and 5) serve as a quick idea
capturing process.\textsuperscript{19}

Sketching is important to the industrial designer because, as Pericles the
ancient Greek statesman said, “a man who cannot communicate his ideas is on the
same plane as one who has no ideas.”\textsuperscript{20}

Experiences in visual language aptitude

\textit{Sketching from memory.} The experience for sketching from memory
involves a series of lists. I asked the students to sketch several lists: grocery
shopping, going camping, and packing for college. The students were given an
allotted time, and were graded on the number of recognizable objects. They were to
sketch the item well enough to be recognized, but fast enough to get a large number
on paper. They could only use visuals, no text or numbers. This is a great
introduction to thumbnail sketches. (small, quickly drawn configuration studies done
more for the study of a visual thought than as a finished work of art).

The dark band on the grocery and camping lists evaluation graphs shows the
class average. This allows the students to see where their score fits with the rest of
the class. A successful list has a large number of recognizable objects (fig. 17). An
unsuccessful list has very few recognizable objects (fig. 18).

\begin{footnotesize}
\begin{enumerate}
\item Thomas C. Wang, \textit{Sketching with Markers}, (New York, Van Nostrand Reinhold), 1993, p. ix
\end{enumerate}
\end{footnotesize}
Fig. 17. Successful camping list

Fig. 18. Unsuccessful camping list
One student came into class late. Out of the 15 minutes given to complete the list she had only about 7 minutes. She got right to work and produced 27 items matching the average in the class. The mean number of items on the list was 28.
Sketching from imagination. Creativity researchers Sternberg and Lubart developed a model for testing their theory of creativity. The model used tasks such as writing short stories with unusual titles (e.g., The Octopus' Sneakers), drawing pictures with unusual themes (e.g., the earth from an insects point of view), devising creative advertisements for boring products (e.g., cuff links), and solving unusual scientific problems (e.g., how we could tell if someone had been on the moon within the past month).21

Here I saw the opportunity to experience three aptitudes at once. I developed a nonsense story that has no recognizable people, places or things. The sequence of the story gives clues to what is happening. The students were asked to illustrate the story in Sunday comic fashion. This gave them an experience with sketching from imagination, dealing with ambiguity, seeing a process, and expressing creativity. I also found that this was an excellent opportunity to observe natural design aptitude. Here is the story:

Last Serny, Flingledode and Pribin were in the nerd-lek treppering gloopycaples and cleaming burfy grips. Suddenly a dutty strezzle boffed into Flingledode's tesk. Pribin glaped and glaped. "Oh, Flingledode," he chifted, "that dutty strezzle is tuning in your grep."

To make sure the students understood the story I asked them the following questions.

When did this happen? Who was there? Where were they? What were they doing? What happened? What did Pribin do? What did he chifted? What was the dutty strezzle doing?

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Every student could answer the questions, which showed that they understood the story. I wanted to see if the student could enhance the understanding of the story by drawing it in comic fashion. The old Chinese proverb says, "A picture is worth a thousand words." The first example (fig. 22) was an excellent example of producing the result that was expected. The picture helps to clarify the story. We now know what the nerd-lek looks like. We know what Flingedode and Pribin look like and we know more about treppering gloopycaples and cleaming burfy grips. We know what a dutty strezzle looks like and we have an idea of what a grep is and how the dutty strezzle tuned in it.

Fig. 22. Successful Flingedode and Pribin experience
The second Flingedode and Pribin example doesn't help us understand the story better but actually further confuses the story (fig. 23).

Fig. 23. Unsuccessful Flledgedode and Pribin experience

Modeling is also part of the visual language and crosses over into mechanical aptitude. A number of responses to the aptitude survey mentioned things such as: likes to work with his hands, makes things, did well in shop classes, and plays with Legos. This is another way that visual people express their ideas. If a picture is worth a thousand words, then a model must be worth a thousand pictures.

**Mechanical Aptitude**

During my college years I made a friend. His father owned a local automotive repair shop. He was looking for help and I needed a job. Luckily my association
with the friend helped me land the job. We both started work at the same time. The shop did a good business in after-factory air conditioning. Someone would buy a new car and ask the dealership to install air conditioning. They would bring the car to the shop and we would do the installation. This was new to both my friend and me so we were trained on how to do the installation. Soon I was able to install 3 air conditioners in a day. My friend was doing 1 every 2 days. One day the boss asked me to help my friend with an installation he was struggling with. I went over and in a few minutes saw the problem. I didn't want to appear condescending to my friend so I casually pointed out the problem. He looked and couldn't see what I was talking about. I pointed it out again and he could not see the solution. Up until that moment I had thought that everyone thought like I did. I realized that what I could see clearly was not apparent to my friend. I had heard all my life about mechanical aptitude but I didn't understand what it meant until my experience. Not to worry, within a few weeks my friend was promoted to work in the front office.

An important aspect of visual thinking is that one can perceive the whole, the parts, and there relationship to each other. It makes a visual thinker good at what Visual Thinking calls, ...the ability to see visual shapes as images of the patterns of forces that underlie our existence - the functioning of.... machines.22 "Spatial concepts go hand-in-hand with mechanical ability."23 Mechanical ability is not only curiosity and understanding how things work but also the desire to build things.

"Tool making and tool using, ...depend heavily on high level visual processing. A

23 Mechanical and Spatial aptitude, (New York, Learning Express, 2001) p. 2
A verbal description of how to make or use a tool is unlikely to succeed if the learner cannot visualize the steps or techniques in the process.²⁴

Basically, mechanical ability means that you can understand mechanical principles, devices and tools, and the everyday physics that make them work. You also have the ability to reason and understand the direction of movement of gears in a system of gears. In addition, you can see the pattern of moving parts in engines and machines.²⁵

Mechanical aptitude also includes a sense of assembly, a sense of structure, and a curiosity about how things work.

The most consistent aptitude noted on the survey was “curiosity about how things work.” Curiosity is a desire for learning or knowing, to be inquisitive, an approach to life, the impulse that leads you to wonder and ask, “Why?” But more than that, it is the motivation to discover the answers. Curiosity is a desire for learning about anything.

I visited the Seattle Museum of Art a few years ago to see the Leonardo da Vinci codex that Bill Gates had purchased and graciously displayed for public view. The codex was a series of sketch and notebooks that Leonardo had made in his observations of water. According to the information presented at the museum, Leonardo did more research and study of water than any other thing. His sketches showed what would happen if you put a small stick in the water. What was the effect on the stream? If you put the stick in at an angle with the stream what was the effect? If you put the stick in at an angle against the stream what was the effect? Then, slanted side to side. Each of the effects were sketched and notes were


²⁵ Mechanical and Spatial aptitude, (New York, Learning Express, 2001) p. 2
written about his observations. I thought of the hours he must have spent observing and sketching these effects. Why? I think he was curious about how things worked. His curiosity led him to explore, observe, record and learn about the things around him.

Curiosity is tied to creativity. It is the force behind our making connections. Curiosity is born out of the creative mind because it asks the questions, why, how, what, and if. This is one of those crossover points between visual thinking and creative thinking.

Experiences in mechanical aptitude

*A motion conversion model.* This experience required the students to build a model that converts motion from one form to the other, four times. They used circular, circular incremental, vertical linear, vertical incremental, horizontal linear, horizontal incremental, angular, and angular incremental. The materials and the size and orientation of the base were specified (fig. 23). The requirement is that the model be robust enough to work through several iterations.

I also placed very specific information in the instructions as to the placement and size of their name on the model (fig. 24). I used this as an example of ambiguity. We don’t know what the product is yet, but we do know where the logo will be, how big it should be, what color it will be and where it will be placed. The result of this experience can be categorized into three levels. 1) The model worked well and accomplished the tasks. 2) The model was not robust enough to work
continually. 3) The model was not attempted. Fifteen students out of a class of twenty-four accomplished something on the assignment.

**Motion Model**

Part of being an industrial designer is understanding how things work. This activity is designed to give you an experience with how things work.

The objective of the experience is to build a model that is a working mechanism. The mechanism will convert motion from one form to another four times. For example, convert circular motion to linear motion to angular motion to incremental motion. You can pick the motions that you want to model.

Requirements:

The Model will be built out of foam core and a wooden dowel. Foam core can be purchase at the tool crib for $.75. Dowel's can be purchased at the book store.

The base for the model must be 11'' x 14''.

Follow the directions for the placement of you name on the model. (see logo placement instructions)

Use only 3/16'' foam core, 1/8'' dowel, rubber bands, and glue.

The model is to test your mechanical ability and your craftsmanship. Use care in the building of your model.

The mechanism must be robust enough to work through repeated use.

**Motions:**

- Circular
- Incremental circular
- Horizontal linear
- Horizontal incremental linear
- Vertical linear
- Vertical incremental linear
- Angular: 45 degree, 90 degree, 180 degree

**Logo placement instructions:**

125'' border all around name

Name in 24 Point Helvetica bold italic

NAME

5'' border bottom and side

Print out your name out to size specified and adhere to the corner of you model platform.

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Fig. 24. Instructions for motion model experience

Fig. 25. Motion model experience samples
**Mechanical principles kit.** The students were given a zip lock bag with a variety of items (popsicle sticks, short dowels, rubber bands, wooden wheels, old CD's, flexible straws, plastic spoon, piece of string, thumbtacks, empty thread spools, etc.) (fig. 26). They were to use the items to build a machine that would accomplish something (travel a certain distance, jump in the air a certain distance, pull a certain weight, etc.). We did not have time to test this experience in the class.

![Mechanism experience kit](image)

*Fig. 26. Mechanism experience kit*

**A processes.** This experience uses Rube Goldberg's cartoon as a model. The students were asked to sketch a Rube Goldberg-like cartoon that accomplishes some task such as: turn on the light, put out the cat, get you out of bed. The students were to show this process with a minimum of 8 steps. They were not to
use text or numbers, only an indication of the starting point. This was a timed, in-class assignment. After the time was up we had someone other than the person who drew the cartoon come up and walk the rest of the class through the steps. This acted as a critique and helped the students see how connected and clear their process was.

This experience was to test for the students aptitude to visualize process, understanding of everyday physics, and drawing from memory and imagination. One of the aptitudes or attitudes that was mentioned a number of times in the research was that an industrial designer should have a sense of humor. This gives the student an opportunity to express a sense of humor.

In a successful experience, one can follow the process from the beginning to the end result (fig. 28). In an unsuccessful experience, a process is shown but the process may not be linked together. You don’t see the cause and effect, which is an essential part of the process (fig. 29). Another unsuccessful experience, the process is never finished. The student tried to write out the experience first and then draw the process (fig. 30). I had one student on this assignment that could not come up with anything. They sat and stared at the paper for the whole time. In the end they had two steps that they borrowed from the Rube Goldberg cartoon I handed out as an example.
Fig. 28. Successful Rube Goldberg experience

Fig. 29. Unsuccessful Rube Goldberg experience 1
Aesthetic Aptitude

A number of survey responses were related to sensitivity to form, feel for color, and a natural design sense. Design principles of proportion, balance, color, shape, interest, emphasis, and craftsmanship can be taught, but some individuals have an aptitude for them. The aesthetic aptitude is recognizable in many of the assignments. The power of the aesthetic aptitude is that it brings form and organization to the chaos of creative thought. Again, design principles can be taught but some students seem to have a natural aptitude.

Seymour Chwast, an accomplished designer says, “Drawing broadens your range of solutions. It forces you to value concept over style. When you learn to draw,
you learn to organize form and break up space. With drawing, all the principles of design come into play."26

Steff Geissbuhler, partner at the New York firm of Chermayeff & Geismar says, "I don't think you can learn to see without drawing. If you've never drawn a letterform, for example, you can't understand its architecture, its balance, its means of support, and the logic of its proportions."27


Experiences in aesthetic aptitude.

The experience for measuring this aptitude was to evaluate the design sensitivity of all the projects. The aesthetic aptitude will provide for form as well as content in the students work. I looked a variety of assignment for the aesthetic aptitude. Examples of this are shown in the process notebooks I had the students submit at the end of the class. Every student was given the same instruction but the result was different. Some were more aware of the aesthetic of the notebook (fig. 31). Some were not aware of the aesthetics of the notebook (fig. 32). This assignment was a final in the class and so the feedback for the students evaluation was not completed.


27 ibid.
Creative Thinking

After reviewing 22 definitions of creativity, P. K. Welsh found significant levels of agreement of the key attributes of these definitions. She proposed the following definition from her review of the literature:
"Creativity is the process of generating unique products by transformation of existing products. These products, tangible and intangible, must be unique only to the creator, and must meet the criteria of purpose and value established by the creator."

Isaksen and Treffinger defined creativity as making and communicating meaningful new connections in order to think of many possibilities, think and experience in various ways and use different points of view, think of new and unusual possibilities, and guide in generating and selecting alternatives.

A creative ability is manifest in creative behavior, which includes such activities as inventing, designing, contriving, composing, and planning. People who exhibit these types of abilities to a marked degree are recognized as being creative. Creativity is the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints).

I was resisting using the term "creativity" at the beginning of the research. It has a connotation of having total freedom to do whatever you want, which is not applicable to design. Frank Lloyd Wright said, "Man built most nobly when limitations were the greatest." I wanted to use a word more closely associated with the design process like innovative or inventive. What I found was that the difference in terms was only a point of view. What is the difference between creativity and innovation? I think the difference is point of view, The Handbook of Creativity defines the difference as, "Business dissertations used the term innovation, whereas


32 Frank Lloyd Wright, (http://www.geocities.com/SoHo/1469/flwquote.html)
psychology dissertations used the term creativity."33 Creativity is the term that I will use in this paper.

Creativity is a quality that is highly valued, but not always well understood. Those who have studied and written about it stress the importance of a kind of flexibility of mind. Studies have shown that creative individuals are more spontaneous, expressive, and less controlled or inhibited. They also tend to trust their own judgment and ideas--they are not afraid of trying something new. A creative person is curious, seeks problems, enjoys challenges, is optimistic, is able to suspend judgment, is comfortable with imagination, sees problems as opportunities, sees problems as interesting, challenges assumptions, doesn't give up easily, perseveres, and works hard. The creative person also has difficulty following through, is not realistic or practical, and has trouble focusing.

It is possible to teach and develop one's ability to think creatively. Some seem to have a natural aptitude for creative thought. Many tests have been developed to test for creativity. Torrance developed a series of tests for divergent thinking and other problem solving skills. Some of the tests from the Torrance battery include the following:

Asking questions: The examinee writes out all the questions he or she can think of, based on a drawing or scene. Product improvement: The examinee lists ways to change a toy monkey so that children will have more fun playing with it. Unusual uses: The examinee lists interesting and unusual uses for a cardboard box. Circles: The examinee expands empty circles into different drawings and titles them."34

34 ibid., p. 8
Other tests include writing short stories with unusual titles (*The Octopus' Sneakers*), drawing pictures with unusual themes (the earth from an insect's point of view), devising creative advertisements for boring products (cuff links), solving unusual scientific problems (how we could tell if someone had been on the moon within the past month). The tests are scored for fluency (total number of ideas), flexibility (number of different categories of relevant responses), originality (the statistical rarity of the responses), and elaboration (amount of detail in the responses).

Part of the SOI (Structure of Intellect) battery of tests for creativity, as summarized in Guilford,\(^\text{35}\) consists of several tests where the subjects were asked to exhibit evidence of divergent thinking in several areas, including semantic units (e.g. listing consequences of people no longer needing to sleep), figural classes (finding as many classifications of sets of figures as is possible), and figural unites (taking a simple shape such as a circle and elaborate upon it as often as possible.

Another variation of tests ask students to list as many things that move on wheels (things that make noise, etc.) as possible, and on variations of uses. Students provide responses to "tell me all the different ways you could use a chair, newspaper, knife, tire, brick, pencils, toothpicks, or a paperclip."\(^\text{36}\)

I have focused on three aptitudes that were mentioned in our survey and I think are most applicable to industrial designers. These aptitudes are: The aptitude


\(^{36}\) ibid.
for problem finding and defining, the aptitude for combining and connecting ideas, and the aptitude for perceiving things in an un-habitual way.

Aptitude for Problem Finding

E. Davidson gives us a good “problem” definition, he defines it as:

All problems contain three important characteristics: givens, a goal, and obstacles. The givens are the elements, their relations, and the conditions that compose the initial state of the problem situation. The goal is the solution or desired outcome of the problem. The obstacles are the characteristics of both the problem solver and the problem situation that make it difficult for the solver to transform the initial state of the problem into the desired state. Problem solving is the active process of trying to transform the initial state of a problem into the desired one. [Creativity] helps the problem solver (1) recognize that there is a problem to be solved, (2) figure out what exactly the problem is, and (3) understand how to reach a solution.37

Naturally creative people have the ability to see things in the context of the whole and also focus on the details. This was mentioned a couple of times in the aptitude survey. This skill is essential in problem finding and defining.

The relationship between creativity and problem solving is a very close one in the minds of many investigators. Problem solving has to make a distinction between problem finding and problem solving. One is divergent thinking or hypothesis generation and the other is convergent thinking or hypothesis testing. Creative abilities such as fluency, flexibility, and originality are in reality indispensable components of realistic and complex problem solving behavior.38

There is a difference between presented and discovered problems, and creativity is associated with the discovery or the finding, recognizing, defining, or refining a problem. I believe that design is about finding the right question; answers

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are easy if you know what the question is. I have found in my research a number of authors that agree with this idea. Biccar S. Randhawa says, "My answer is that the question is the more difficult to find and, hence, the more important. It is relatively easy to learn what to do after one has a question." Robert J. Sternberg records, "Problem finding involves, one might say, thinking about what to think about." "The formulation of a problem is far more essential than its solution," said Albert Einstein. John Dewey expresses the same idea, "A problem well stated is half solved."

As Jeffery Freed says, "Because one of the attributes of right brained thinking is a non-sequential divergent form of thinking, the right brain minds often veer into unusual and different territory. This can result in illogical or often unsubstantiated conclusions. On the other hand, they may view a problem from an entirely different angle, leading to new breakthroughs and discoveries." Robert W. Olsen in his book *The Art of Creative Thinking* describes why creative people are good problem solvers.

Creative people have a higher motivation to, and capability for, recognizing: valuable problems. They are able to bring to a clear focus the exact nature of a problem and engage their conscious and unconscious minds to solve it. They are receptive to their own ideas and those of other people. They combine judgment and intuition based on their knowledge

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42 Abid.

and experience to select the best solutions. And they have the energy and commitment necessary to transform their ideas into usable results.44

Unfortunately, problem finding has not been a major focus of education; students are typically given problems to solve and are seldom taught to search out problems for themselves.45

The problem of problem solving without problem finding is that you might solve a perceived problem and not a real problem, or solve a symptom of a problem and not the problem. You might solve only part of the problem, or solve the wrong problem.

Jerry Hirshberg tells a story in his book about a heated discussion between the Japanese management and his design group:

The project was running late due to a growing, almost obsessive need on the part of the Japanese to restudy, research, and refine every detail. In a moment of frustration at the meeting I said, “Gentlemen, aspects of this design are truly new, and if we don’t get it to market soon, we simply won’t be first!” The project leader leaned forward, somewhat agitated, and responded, “Hirshberg-san, we were thinking about being best!”46

A few years ago one of my clients was a bar code scanning manufacturer. The concept of scanning in the grocery store is to speed the check out process. Someone in our company came up with a great idea to get people in and out of the store very quickly. Unfortunately, the problem was a hard sell to the grocery industry that makes over 50% of its revenue from impulse buying. The industry takes great efforts to make people wander the isles while passing by many items, hoping they

take their time shopping. In fact, a whole new discipline has developed around this very subject, retail anthropology. When shoppers are ready to check out that's when you want them to move quickly and efficiently.

Experiences in problem finding

I used part of Guilford's SOI (Structure of Intellect) battery of tests for creativity where a student is to show evidence of divergent production by listing as many consequences as one could think of using the statement: What if people no longer needed sleep?47

The experience was evaluated on number of ideas and originality of ideas. (fig. 31) All the lists were compiled, and I asked three other designers to help me pick out ideas they thought were the further reaching concepts. We compared the three lists and assigned weight to items on the list. The evaluation reflects the number of items, but also added points for originality of ideas.

Fig. 31 Problem finding evaluation

Some of the more creative ideas were: "twenty seven years more time to do things," "in Japan there will be more space available because beds will not be needed," "we can travel greater distances at a time," "more meals in a day," "people would find ways to replicate dreams," "lots of new night time products," "businesses would work at night and you would have the day off," "people would evolve to have night vision," "no need for bedrooms," "no conclusion or start of a day," "couldn't sleep off a sickness," "our language would change to eliminate many words," "babies cry less," "can't put kids to bed as punishment," "metabolisms would increase," "no nap time at kindergarten," "lullaby's would be pointless," "no hotels and motels as we know them," and "showers wouldn't be crowded in the morning."

Often problem finding is about asking questions. "The important thing is not to stop questioning. Curiosity has its own reason for existing."48 The second experience in problem finding asks the student to write out all the questions he or she can think of in relation to improving a product.49 The student then lists product positives and negatives. For each negative listed the student is to suggest an improvement.

The Aptitude for Combinations and Connections

"The ability to relate and to connect, sometimes in an odd and yet striking fashion, lies at the very heart of any creative use of the mind, no matter in what field

48 Albert Einstein, (http://stripe.colorado.edu/~judy/einstein/knowledge.html)

of discipline,” says George J. Seidel.\textsuperscript{50} Thus, creativity is the ability to see connections and relationships where others have not. The ability to think in intuitive, non-verbal, and visual terms has been shown to enhance creativity. Creativity is the ability to make “combinations of previously unrelated structures in such a way that you get more out of the emergent whole than parts you have put in.”\textsuperscript{51}

A common misunderstanding equates creativity with originality. In point of fact, there are very few absolutely original ideas. Most of what seems to be new is simply a bringing together of previously existing concepts in a new way.\textsuperscript{52}

The random-word method is a powerful lateral thinking technique that is very easy to use. It is by far the simplest of all creative techniques and is widely used by people who need to create new ideas. Chance events allow us to enter the existing patterns of our thinking at a different point. The associations of a word applied to the new out of context situation generate new connections in our mind, often producing an instant insight or direction. Random inputs can be words or images.

The brain is a self-organizing system, and very good at making connections. Almost any random word will stimulate ideas on the subject. Follow the associations and functions of the stimulus word, as well as using aspects of the word as a metaphor.\textsuperscript{53}

\textsuperscript{50} Kurt Hanks, Jay A. Parry, \textit{Wake Up Your Creative Genius}, (Los Altos, CA, William Kaufmann, Inc.) p. 6

\textsuperscript{51} abid.

\textsuperscript{52} abid., p. 7

A good way to turn your mental attic of experiences into a treasure room is to use trigger concepts - words that will spark a fresh association of ideas in your mind. Like pebbles dropping in a pond, they stimulate other associations, some of which may help you find something new.54

No one truly creates, that would be making something from nothing. Two old ideas combined in a new way form a new idea. These combinations are at the root of innovation or creation. The idea is to develop a series of experiences in forcing new relationships and combinations.

Books on creativity are full of techniques to enhance creative ability. Almost all these techniques are to help us make new connections or combinations. Most creativity techniques are to get us to view things differently then we have before. Techniques force our thinking down an uncomfortable path. These techniques include: random input, problem reversal, asking questions, lateral thinking, checklists, brainstorming, forced relationships, analogies, attribute listing, PO (Provocative Operation), mind mapping, and metaphors.

Experiences in combinations and connections

**Combinations.** This experience uses the “random word association” technique. The students were asked to design a camera, and then they were given a random word. They were to use the word to help them generate ideas for the camera (fig. 32). It was explained that they didn’t need to use the word literally, but the word could be used as a metaphor, and they shouldn’t use the word to define the appearance but also the function.

The results were evaluated on fluency, flexibility, originality and elaboration, as prescribed by Robert Sternberg, in his book, *Handbook on Creativity*. "Typically creativity tests are scored for fluency (total number of relevant responses), flexibility (approaching the problem from a number of directions), originality (the statistical rarity of the responses), and elaboration (amount of detail in the responses)."\(^{55}\)

One student did well on flexibility (fig. 32). The word was "pyramid," and her explanation of the concept behind her camera shows good flexibility. She explained that a pyramid was a place where everything was put that a pharaoh would need in his next life. That made her think of a Swiss Army knife with everything you need in one spot. That led to the design.

Another student whose word was “pebble,” (fig. 33) did well in fluency but not in flexibility, originality, and elaboration.

Fig. 33. Random word camera experience 2

A student whose word was “sun,” (fig. 34) did well in flexibility, originality and elaboration but not fluency.

Fig. 34. Random word camera experience 3
Connections. The rules of brainstorming and other connection tools are all similar. The concept is to have fluency, flexibility, and originality. The problem is defined and stated, and the members of the brainstorming session are encouraged to come up with as many ideas as the problem brings to mind. Ideally, the members of the session are from different disciplines, which provide the flexibility aspect of ideas. There is no elaboration or critique of the ideas. Quantity, not quality, is the goal of the session. The purpose of the session is to "spark off" of other people's ideas.

Brainstorming is a very popular creative problem solving technique. I have been a part of numerous brainstorming sessions in my career. The process goes like this: a group of engineers stuck on a problem call for a brainstorming meeting. In the meeting the problem is defined and the rules of brainstorming are reviewed. There are no critiques, just a free flow of ideas. When the ideas start to come, someone then says something outrageous and the group laughs. After a good laugh the facilitator says, "OK, let's get back to business," or "Let's stay focused." In reality, the first creative idea was just spoken, but no one recognizes it. What makes us laugh? It is the lateral thinking process. A joke takes us down a path and we come to an illogical conclusion. The jump in tracks makes us laugh.

This next experience is for students to see the power of making connections. The instructor draws an image of Abraham Lincoln in a bathtub on the board (upper left in fig. 35) and asks the students to guess what it is. When the students have guessed, the instructor asks them add 100 more items. I have tried this experience six times. The students are always doubtful that they can do it, then surprised at

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how easy it is. Why? Each student who draws an idea makes a connection with an idea in another student's mind. The ideas flow quickly and easily.

Fig. 35. Brainstorming experience 1

Fig. 36. Brainstorming experience 2
Aptitude for Un-habitual Seeing

Woodrow Wilson said, "Originality is simply a fresh pair of eyes." And William James says that, "Genius in truth means little more than the faculty of perceiving in an un-habitual way."57

One of the companies I did work for had an engineer that all the other younger engineers called "the expert." He had had a long career in the industry, and so, had an answer for every problem based on his long experience. We were designing a single line, receipt printer for the banking industry. We came up with what we thought was an innovative mechanism to drive the paper, and it only used a single roller. When we presented the idea, "the expert" said it couldn't be done, he had tried it before, and it wouldn't work. One of the other more creative engineers took it upon himself to prove "the expert" wrong, and he did. Our single roller worked and the product was very successful for the company. I had a conversation with "the expert" and I asked him when he found a solution to a problem how did he know that it was the best solution. If there were ten solutions to the problem, with the tenth one being the best, how did he know that he wasn't using the fifth as his solution to the problem? Each time he found the same problem he used the same solution. His answer was that he knew that it worked, and that was what was important. Experience can be a detriment to creativity because we stop searching (fig. 37). Einstein said, "Remember that good ideas are the greatest obstacles great ideas have to overcome."58

58 Scott Thorpe, How to Think Like Einstein, (Naperville, IL, Sourcebooks, Inc. 2000) p.
When I decided to be a teacher I thought one of my strong points was the breadth and depth of my experience. Now I wonder if that could be a detriment to my teaching abilities.

What I call un-habitual seeing is also called rule breaking, rut jumping, paradigm shifting, thinking outside the box, and an open mind. All these terms describe the ability to view things in a new light.

Experiences in un-habitual seeing

*Recycle.* The first experience with un-habitual seeing is called recycle. It asks the student to look at something in a new way. Find a discarded object and find a new use for it (fig. 38, 39, 40).
Fig. 38. Recycle experience--Film negative luminary

Fig. 39. Recycle experience—CD picture holder
Excursion. The second experience is called excursion. I asked the students to design a picture holder. Without a preconceived idea of what to do, the students wandered into a hardware store looking at everything as a possible means for holding a picture. [Each student picked the idea he or she liked and used the idea to design the product. (fig. 41, 42) ]
Fig. 41. Excursion experience--Mousetrap picture holder

Fig. 42. Excursion experience--Clear light switch plate picture holder
Flexible Thinking

James L. Adams, in his book, *Conceptual Blockbusting*, says that one block to creativity is fear.

The fear of making a mistake is, of course, rooted in insecurity, which most people suffer from to some extent. Such insecurities are also responsible for the next emotional block, the ‘Inability to tolerate ambiguity...overriding desire for order; and no appetite for chaos.’ I am not suggesting that in order to be creative you should shun order and live in totally chaotic situation. I am talking more of an excessive fondness for order in all things. The solution of a complex problem is a messy process…. problem solving is bringing order to chaos.\(^59\)

I recently met a person who had graduated some ten years ago with a degree in industrial design and, of course, we got into a conversation about the industry. He told me that he was not working as a designer. When I inquired why he told me his story. He complained that his schooling had not prepared him for the “real” world and he was upset about it. When he graduated he got a job with General Electric. On his first day at work, his manager gave him a design assignment. He didn’t know what to do with it. His problem was that the work assignments didn’t follow the process he had been taught and had practiced in school. He struggled along and got more and more frustrated with the experience until he quit after about six months. He had not worked as a designer since.

In another conversation I had with him a few weeks later, he told me he had an interest in teaching design. He said, part joking but part serious, “I would assign the students a project on Friday, and on Monday I would change it, cut the budget or

cancel the project.” I also met a classmate of this student, and he told me that his former classmate had good skills and was creative. That got me to thinking. When he graduated he got a job at G.E., he must have had a good portfolio. Then the picture started to become clear. It wasn’t his training that had gone wrong, it was his ability to deal with the ambiguity of the design world, hence his idea for teaching with a “real world” design assignment. Since that realization I have had other conversations with him that have verified my suspicions. He is very neat and orderly in his life- everything in neat packets. I think he had the visual thinking aptitude and the creative thinking aptitude but was lacking in aptitude for flexible thinking.

There are a number of aptitudes associated with flexible thinking. The three that I wanted to focus on were those most closely associated with the survey. The aptitudes are: Tolerance for ambiguity, intuition, and adaptable to change.

**Tolerance for Ambiguity**

“Some people believe that there is only one right answer and that ambiguity must be avoided whenever possible.”\(^6^0\)

Tolerance for ambiguity refers to the capacity to withstand the uncertainty and chaos that result when a problem is not clearly defined or when it is unclear how the pieces of the solution are going to come together, or whether it will come together at all. When you do creative work, groping along in unclear situations is commonplace. You can go through long periods of time in which you are trying to get the idea but it just doesn’t quite emerge, or emerge the way you would like it to.

For some ambiguity is uncomfortable and anxiety provoking. As a result people strive to resolve it. Moreover, the pressure for resolving ambiguity is often not internal. Often your employer puts as much or more pressure on you as you do on yourself. The problem is that to optimize your creative potential, you need to be able to tolerate the discomfort of an ambiguous situation long enough so that what you produce is the best or close to the best of which you are capable.

Many times in my consulting career clients would apologize, “We don’t really know what we want.” I would say “That’s O.K. We will start to generate some ideas and you can pick the ones that are close and discard the ones that aren’t.” Both kinds of ideas are valuable in defining the direction.

S. Budner says,

Tolerance for ambiguity refers to the extent to which individuals are threatened by or have difficulty coping with situations that are ambiguous, where change occurs rapidly or unpredictably, where information is inadequate or unclear, or where complexity exists.61

The educational system in our country, for the most part, works to eliminate any ambiguity. Most of our testing is defined in such a way that there is only one right answer. It’s A, B, C, or D, True or False. The truth is in design there can be lots of right answers.

The ability to handle ambiguity is a critical skill that many students lack and our educational system’s methods neglect. For designers to feel satisfaction in their careers, they must have a tolerance for ambiguity. Individuals differ by nature in their tolerance of ambiguity. A degree of tolerance can be learned, but it helps that some have an aptitude for it.

61 S. Budner, Intolerance of Ambiguity as a Personality Variable, (Journal of Personality, 30,1962), p. 29
If students are to have experience with ambiguity, teachers must allow the student to experience ambiguity and deal with it. A teacher, in effect, should get out of the student’s way and let one experience things for oneself and not through the teacher. This experience would give students a taste of ambiguity and enliven their creativity.

Experiences in ambiguity

The experience for ambiguity is a simple one. I have the students take an Internet based “Tolerance for Ambiguity” test and record their score.62 (fig. 42)

Fig. 42. Tolerance for ambiguity experience evaluation

The scale measures Intolerance for ambiguity so that higher scores mean more intolerance or less tolerance for ambiguity. A lower than average score means you have a higher tolerance for ambiguity.

62 www.academic.dt.uh.edu/~averf.toler.html, see appendix 6
Aptitude for Intuition

In the 1980’s, the American Management Association published a study concluding that the most successful managers were distinguished by “high tolerance for ambiguity and intuitive decision-making skill.”⁶³ What is intuition? Frances E. Vaughan defines it as a “way of knowing...recognizing possibilities in any situation.”⁶⁴ Laurence R. Sprecher says that intuition is really a subset of logical thinking, one in which the steps of the process are hidden in the subconscious portion of the brain.⁶⁵

Intuition, as an aptitude, allows a designer to make decisions where there is a high level of uncertainty, there is little precedence, variables are not predictable, facts are limited, time is limited, facts don’t make the way clear, and it is necessary to choose from several plausible ideas.⁶⁶ All of these situations are part of an industrial designer’s daily routine. According to Weston H. Agor, intuition is not a guess, good intuitive decisions are based in part on “input from facts and experiences, combined and integrated with a well-honed sensitivity and openness to other, right-brain clues.”⁶⁷ In the book, The Intuitive Edge, Philip Goldberg recommends, “adopting a certain playfulness and an appreciation of whimsy” and “brainstorming with yourself...play freely with ideas without a specific goal in mind.”⁶⁸

⁶⁴ Frances E. Vaughan, Awakening Intuition, (Garden City, NY, Anchor, 1979), p. 3.
⁶⁵ Laurence R Sprecher, Intuition Anyone?, (Public Management, February 1983), p. 18
⁶⁷ Weston H. Agor, (Business Horizons, Jan.-Feb., 1986), p. 41
Intuitive people “trust their feelings, their unconscious thoughts, in addition to their conscious, deliberate, step-by-step, systematic thinking. They are able to wait until a solution arrives which feels right and is logically right. They rely on their unconscious mind to help select the final solution to the problem.”

No experience has been developed for this aptitude. This will be an excellent opportunity for future research.

Aptitude for change

One model for change is defined as a process including four states: 1) status quo, the initial state of the system—comfort, familiarity, established patterns, relationships and routines. 2) Foreign element, some element enters or arises, and interferes with the status quo. 3) Chaos, once the foreign element is recognized and accepted, the system enters chaos, a time of anxiety, vulnerability, and anger. 4) Integration, a transforming idea emerges, and people figure out how to integrate the change, how to work with the changed situation.

In his best selling book, Who Moved the Cheese? Spencer Johnson uses a mouse in a maze analogy to describe people’s lives. Once the mice find the way to the cheese, they follow the same path everyday to get to the cheese. One day they show up and someone moved the cheese. The rest of the book is about how

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70 Rick Brenner, Esther Derby, People Centered Change, (www.estherderby.com/writing_conf/people_centered_change.html, 2000)
different mice (people) react and handle the change.\textsuperscript{71} Most people are change resisters; designers tend to be change champions.

Designers seem to have a natural desire to change things, to make things easier, better, or just different. They have visions of what things could be like. They conjure up scenarios of the future. Francis Strickland points out the power of this tendency, "Individual metaphors can be a very powerful catalyst for change due to the vivid mind pictures they create—capable of dramatically highlighting inadequacies of the old and the advantages of the new much faster than a persistent logical argument."\textsuperscript{72} The designer is not resistant to change because he knows that change brings new problems and designers like to solve problems. George E. Oliome describes this in his book, \textit{The Change Resisters}, he says,

The innovative-minded person has a different set [of arguments] from the stability-minded one. For one thing, being innovation-minded starts one off with the presumption that as one presses ahead into new things, the unforeseen problem will occur, but can be solved. The innovative person will move into new areas without full knowledge of the problems or how they might be solved.\textsuperscript{73}

If you are not a problem solver then change is always frustrating. Peter Drucker says, "The talk you hear about adapting to change is not only stupid, it's dangerous. The only way you can manage change is to create it."\textsuperscript{74} Designers are in the business of change. They not only don't resist change they are the instigators of change.

\textsuperscript{71} Spencer Johnson, \textit{Who Moved the Cheese}, (New York, Putnam's Son, 1989).
\textsuperscript{72} Francis Strickland, \textit{The Dynamics of Change}, (New York, Routledge, 1998) p. 22
\textsuperscript{74} Peter Drucker Readers Digest, Quotable Quotes, May 2002, p. 73
No Experience has been developed for this aptitude. This is a very difficult aptitude to experience in a classroom environment because change is usually associated with time and time was limited.
Chapter 4

EVALUATION

According to Robert Glaser, “There are at least six types of measurements that can be used to reflect aptitude processes." This research uses the two most basic methods, quantitative evaluation and subjective evaluation. Quantitative is easy to understand, student’s are given a score and a standard to measure the score against. The subjective evaluation is based on feelings, preferences, styles, methods, strategies, emotions and motivations before, during, and after the experience. Each evaluation has its different strengths and weaknesses but when used in combination, these two measures strengthen the communication to the students of their aptitude measurement.

The purpose of this research was to provide experiences in industrial design aptitudes to help the students make decisions about their future study of industrial design. The specific goals were fourfold: to determine the industrial design aptitudes, to design a series of experiences that allowed the student to get a feel for their aptitudes, to test the experiences in a classroom environment, and to determine if the students could self evaluate their aptitudes based on the experiences.

The Experience Laboratory

To test this research in a real environment a laboratory was needed. Rochester Institute of Technology offers a freshman course that is an introduction to industrial design. The conclusion was reached that the freshman course would be an excellent place to try out these experiences with aptitudes. The understanding was that if the aptitude experiences were successful with the students they would become a permanent part of the freshman course. This could address part of problem of the students investing a large amount of time and money in their industrial design education before realizing that they don’t have the aptitude for it.

The class met for 3 hours every Friday afternoon for 10 weeks with an enrollment of twenty-four freshman students. The results of the pilot offering are described in this paper.

The Aptitudes

The frequency by which many of the aptitudes were mentioned in the survey responses gives credibility to the aptitudes selected, even though the sampling of designers was small. Some of the aptitudes mentioned in the survey responses were interpreted to help categorize them, and this interpretation was subjective. The criterion used to categorize the aptitude was whether or not it could stand on its own, independent of the other categories. For example, intuition is often considered a creative thinking aptitude, yet many people who are not creative use intuition to make decisions. Drawing and creativity usually go hand in hand, but there are people who can draw very well who are not creative, and there are creative people who cannot draw. Some of the aptitudes are very hard to test for (e.g. intuition and
adaptable to change) in a classroom environment. The aptitudes were still included in the research to make students aware of what the broader ranges of aptitudes are. These aptitudes were described in lecture and handout to the students in the class. In the future, experiences that incorporate some of these aptitudes could be developed. Some aptitudes were explored more thoroughly than others. More time was spent in the visual thinking category than in creative thinking or flexible thinking. There are two reasons for this: first, visual thinking was the category that had the most often mentioned aptitudes, and second, it is less understood than creativity and easier to test than flexible thinking.

The Experiences

The experiences were designed by adapting more established aptitude tests to meet the specific industrial design aptitudes. This was the best way to formulate an experience quickly and have confidence in its validity. Some of the experiences combine a number of aptitudes into one experience. The opportunity to combine a series of aptitude experiences into one is an intriguing idea. Eventually it would be more effective to provide a smaller number of experiences that would combine a variety of aptitudes. A number of the aptitude experiences were more formal, like a test. Taking the same concept and using it in a more informal way would allow for a more interesting and challenging experience.
The freshman course was the perfect place to try out the experiment experiences. The class had twenty-four students from a number of different majors. Seven students were declared Industrial Design majors, eight students were Graphic Design majors, three were Illustration majors, one was a Fine Arts major, one an Information Technology major, one an Engineering major, one a Photography major, and two deaf students from NTID (National Technical Institute for the Deaf). The male and female mix was exactly even, 12 females and 12 males. Judging by their first day class evaluation, very few had a clear understanding of what industrial design was and what it takes to succeed in the field. The class was introduced on the first day to the structure of the course. They were told it would introduce them to industrial design and the aptitudes that industrial designers need to succeed in the profession. The class was not told about the purpose of the research in order to help them stay objective about the experiences.

The Evaluation

The experiences with aptitudes are not for a teacher’s use as much as for students use. The evaluation was based on two models of aptitude evaluation. Some of the assignments had a quantitative evaluation averaged with the class. The rational behind the averaging of the experiences is that all these students, with the exception of three, were in the College of Imaging Arts and Sciences. They all had some visual arts background. The averaging would be less acceptable if we had a completely random group. Each student could evaluate his experience with the others in the class. The evaluations were anonymous so that the student could
see where he or she fit in the class as a whole, but not to a specific student. Each quantitative evaluation was presented to the class after the experience was complete.

The second evaluation method is more subjective. The students were asked to process how they felt about the assignment. Was it easy? Was it fun? How did you do? The last day of class the students were interviewed individually. Their evaluations were reviewed and discussed, and they were given opportunity to express their feelings about the class.

The evaluation interviews verified the concept of aptitude experiences and student ability to self-evaluate their fit in industrial design. The students who did well on the aptitudes were excited about industrial design. Other students who were looking into industrial design decided that they didn’t feel they had the aptitude for it. Twenty-two of the students evaluated made decisions that matched what the research showed. Only one student who didn’t do well thought he would still like to try industrial design. I have chosen five students to profile as models for proof of the hypothesis.

Student One is an illustration major and took the class because of an interest in changing to industrial design. The student’s father owns a business that has developed several products and has used industrial design consultants. The father was excited about his child’s interest in industrial design. The student even brought in some of the father’s products for an industrial designer’s opinion. Student One’s comments in the evaluation said that they enjoyed the class and it helped her make the decision to stick with illustration. Student One’s aptitudes showed she was good
at visual language and weak with 3D and creativity. The student recognized these weaknesses and verified them in the final evaluation. When asked what aptitudes were weak the student said, "...being creative and thinking outside the box. My products would be pretty but wouldn't work, and the human factors would be weak." When asked if the experiences in the class helped make a decision about industrial design Student One said, "Yes, it did. I would be interested in going into it (industrial design) but I don't think I would do well at it."

Student Two is also an illustration major. The evaluations of the experiences showed good visual language and aesthetic aptitude but not 3D or mechanical aptitude. The student expressed the same in the final interview evaluation. The student recorded, "I think I did pretty average. Some things, like the sketching, I did well on because of my experience, but in the actual constructing of 3D objects and mechanics, I didn't do as well." She admitted, "I realize that I'm better as an illustrator, although ID would be a neat career choice." Other comments made about aptitudes were: weak in 3D, building things, visualizing objects in space, and creating "original" ideas.

Student Three was a graphic design major. The evaluation of all the experiences were high. The student did well on visual thinking, sketching, mechanical, and creativity. Half way through the class the student officially changed his major to industrial design. The student said, "The class helped me and answered all my doubts."

Student Four is an industrial design major. He had studied engineering and had already decided to make the switch. The evaluation showed good 3D
visualization skills, creativity, and high tolerance for ambiguity. Student Four said, "I had already switched in from engineering and it (the class) just reaffirmed my decision."

Student Five is a graphic design major. He had an interest in changing to industrial design. The evaluation of the experiences showed average ability in 3D thinking, creativity and poor mechanical ability. Student Five said that the class helped him understand industrial design better and will help to make a decision, but he was not ready to decide yet.
Chapter 5

CONCLUSIONS

The evaluation of the students was the most exciting aspect of the research, perhaps because it was the biggest unknown. The concern was that the students would not be able to accurately self-access their aptitudes, even when presented with the experiences. The preconceived notion was that the students would rationalize the experiences as not applying to them, or not a fair assessment, or they could do better next time. The amazing thing was that the evaluation almost coincided exactly with the aptitude results.

This research is a work in progress. The scope of the research was much broader than the time allotted. This was understood that from the beginning and the research was approved with the understanding this is a starting point to a much more thorough research on aptitudes, more concisely developed experiences, and more accurate evaluations.

The conclusion is that we can help students recognize their aptitude for industrial design early in their schooling and that the students can use the experience in the class to evaluate their own fit in the field of industrial design with accuracy.

Continuing goals for research in this area are: 1) to continue to collect information from designers about the aptitudes used in industrial design. 2) Research the experiences further and design experiences that combine several aptitudes together. 4) Reduce the number of aptitude experiences by combining.
5) Refine the information and experiences and develop them to be part of or a stand-alone introduction to industrial design classes.
APPENDIX 1

SOURCES FOR INDUSTRIAL DESIGN APTITUDES

Tim Armstrong, VP of Product Design and Development, Pride Health Care
David Gotham, Industrial Designer, Kodak
Mark Panke, Industrial Designer, Xerox
Brian Aiken, Product Manager, Fisher-Price
Craig McArt, Professor of Industrial Design at Rochester Institute of Technology
Paul Porter, Director of Corporate Design and Usability, Kodak
Jim Gresko, Industrial Designer, KEK Associates
Sam Swayze, Director of Industrial Design, Kodak
John Marshall, Professor of Industrial Design at Brigham Young University
Ray Phinney, Industrial Designer, Catscradle Design
Mayra Monnseratte, Industrial Designer, KEK Associates
Anna Shelling, Industrial Designer, Kodak
Richard Fry, Professor of Industrial Design at Brigham Young University
John Staton, Industrial Designer, Kodak
Bruce Leonard, Unit Manager, Kodak
Myself, Industrial Designer, Graduate Student
John Jamieson, Creative Director, Frogdesign
Christopher Alvair, Industrial Designer, Microsoft
Other sources of information:

IDSA, Directory of Industrial Designers.\textsuperscript{76}

Chronicle Guidance Publications on Industrial Designers.\textsuperscript{77}

Micheal J. Gelb, \textit{How to Think Like Leonardo da Vinci}.\textsuperscript{78}

Christopher Lorenz, \textit{The Design Dimension, Product Strategy & The Challenge of Global Marketing}.\textsuperscript{79}

\textsuperscript{76} 2001 \textit{Directory of Industrial Designers}, (Great falls, VA, Industrial Designers Society of America, 2001)

\textsuperscript{77} \textit{Industrial designers}, Brief 126, (Moravia, NY, Chronicle Guidance Publications, 1998)

\textsuperscript{78} Michael J. Gelb, \textit{How to Think Like Leonardo da Vinci}, (New York, Dell Publishing, 1998)

Robert Glasser in his book, *Aptitude, Learning, and Instruction*, proposes that we can use aptitude information in a number of ways. He outlined five models for possible aptitude information application.

The key to aptitude research is to increase the learning potential of the student. We have discussed aptitude and learning but have not investigated the third element of the equation, that is instruction, adaptive instruction. The general concept of adaptive instruction is that the teacher, the student, and the technique vary based on information about a student's aptitude. I have described some general models illustrating different ways that aptitude information might be adaptive to student performance, particularly the extent to which a system provides different instructional programs based on assessments of the student's initial entering state and on continued updating of student performance. Five models, ordered by increasing adaptability to student performance, are briefly mentioned here.

Model I, which can be called a selective model with a fixed instructional path, optimizes educational outcomes by selecting students whose entering ability levels indicate a high probability of attaining particular competencies in a relatively fixed instructional environment. The adaptive decision is to select or reject individuals for an instructional program on some measure that predicts their success through the program and achieving the competencies it teaches.
Model 2 is less selective than Model I and focuses on the development of initial competence. In this model, strengthening initial ability so the individual can achieve the entering skills required by a fixed instructional program and its established competence goal optimizes performance. In this case, individuals are not only assessed with respect to the presence or absence of abilities that allow them to profit from the instructional program but some diagnosis also is made of the nature of these abilities. Adaptation takes place through an attempt to develop these abilities (prerequisite knowledge and aptitudes) so that an individual’s probability of success in the program of instruction provided is increased. Thus, this second model essentially attempts to improve initial competence.

Model 3 focuses on accommodating individuals as a function of their ways of learning and the nature of their achievement. This model, like those already mentioned, holds goals constant, but it modifies instruction on the basis of entering skills. Again, assessment is made of an individual's entering competence, but in this case, the attempt is made to match abilities to different and appropriate instructional programs. The model assumes that alternative means of learning can be matched to the abilities and levels of competence of different individuals. This matching is a more or less continuous process that occurs throughout the course of learning. As information is obtained about student performance, this information is used to make decisions about instruction that will enhance the probability of a student’s success in achieving the goals of the program. The goals of the program are not altered for different individuals, and the attempt is made to allow different individuals to attain generally recognized achievements through different learning experiences. Model 3
essentially accommodates two different styles, readiness for learning, and progress in attaining the goals of instruction.

Model 4 is a combination of Models 2 and 3. The probability of attainment is increased both by improving the abilities required for profiting from the instructional programs available and by providing flexible environments in these programs by which matching can occur. In this model, both initial state and continuous adaptation to the progress of learning modify the instructional program.

Model 5 is like Model 4 but different from the other models in the nature of the achievement attained at the end of the instructional program. In this model, optimization of performance considers all three aspects of instruction—entering ability, learning skills, and differential goal attainment (or qualitatively different competencies). In contrast to Model 5, Models 1 through 4 assume common goals of instruction. For example, all individuals attain certain fundamental literacy—the literacy of elementary school or particular job performance. However, instruction over the long term produces different constellations of abilities, different forms of achievement, and different goal aspirations and interests. Instructional programs, then, vary to the extent that they attempt to optimize similar (singular) or different (multiple) attainments among individuals. Some degree of each of these aspects is present in all instructional systems, but it is apparent that instructional programs change from singular to multiple as one moves from elementary to more advanced schooling. In general, singular and multiple attainment systems also represent changes in advanced education as one proceeds from learning general fundamentals to attaining high levels of individual specialization. Adaptation to
individual differences, in this context, can refer to the extent to which a program of instruction encourages eventual differential achievement—that is, adapts in their interests, talents, and specializations.

The development of adaptive instructional systems requires movement away from fixed-track programs like Model I, toward the more flexible programs outlined in the other models. Progress in this direction will rely on two kinds of work: (1) field research with experimental school programs; and (2) research and theory construction on individual differences, learning, and cognitive performance as these relate to the acquisition of complex knowledge and skill. Work of the first kind should result in the development of global models of instructional systems that link population characteristics, curriculum organization, classroom activities, and student progress. Techniques of causal analysis that apply more directly to field studies than to controlled laboratory situations will be useful for this purpose. The outcome to be anticipated is a macro theory of teaching and instruction—"macro-" in the sense that it is concerned with the large practical variables dealt with in schools, such as the allocation and efficient use of time, the structure of the curriculum, the nature of feedback and reinforcement to the student, the pattern of teacher-student interaction, the relationship between what is taught and what is assessed, the degree of classroom flexibility required for adapting to learner background, and the details of curriculum materials. Such variables need to be part of a theory of instruction in the same way the large variables of economic theory are applied to economic change. As theory at this level develops, it will be under girded by the
more micro-studies of human intelligence, problem solving, and learning such as fill these volumes.\textsuperscript{80}

In this paper the terms visual thinking and spatial thinking are used in the same context because many writers use the terms synonymously. There is a difference between spatial and visual thinking as pointed out by Howard Gardner in *Frames of the Mind*, "an expression of the spatial intelligence sometimes discussed under the label of "visual thinking" (as used, for example, by Arnheim; Samuels; McKim) that spatial intelligence is not exclusively tied to the visual sense; it can develop even in a blind person."81 One of Gardner's recurring themes comes back to mind at this point: "In no case is an intelligence completely dependent upon a single sensory system, nor has any sensory system been immortalized as an intelligence."82 "Spatial" is therefore more than "visual" and includes abstract, analytical abilities that go beyond seeing images. Spatial thinking is a way of organizing things in ones head. It is not visual (though some people think visual and spatial are synonymous) but involves connections between things in a format like 3-dimensional or more-dimensional space.

82 ibid., p. 68
QUESTIONS ABOUT APTITUDES

Questions about aptitudes research are: Does the cognitive thinking style of the individual student in given classroom influence his learning ability? Does thinking style determine how a student might learn best? Does thinking style determine what a student chooses to learn? Does thinking style interact with teaching method to produce different optimum learning situations for students with differing cognitive styles? Does the type of teaching method to which students are exposed effect any change in their cognitive styles? Can we design teaching methods to facilitate particular students with particular cognitive styles? Do different types of materials used in the presentation of stimuli to students interact with students’ cognitive style or influence the learning outcome?83

APPENDIX 5

VISUAL THINKING AND EDUCATION

Our society doesn’t deny the value of visual thinking; but there is a severe lack of awareness and a policy of support, respect and encouragement. As a result, visual thinking is underdeveloped. At the same time, our verbal language—and our structured way of thinking—is becoming more entrenched. In most cases, the visual-spatial learning style is not addressed in school, in fact in many cases it is discouraged, and students with this learning style self-esteem suffers. As children we naturally draw, it is an effort to exercise our visual skills, but within the first few years of school, visual thinking activities are replaced by exercises with words and numbers. I’m not arguing against an education of verbal literacy—these skills are crucial for success in any field. Instead, my concern is that visual thinking gets left behind. And because of that, our society suffers.

Why don’t we value drawing? Wendy Richmond asked the same question, she says, “I ask myself this question often, and the answers I come up with are the obvious ones: works of art have no productive function in our economy, art is politically dangerous, contemporary art is too difficult to understand. So I asked the owner of my favorite café, because he is Italian. He pointed to my notebook and said, “In Italy, school children have notebooks with grids, in America, you have
notebooks with lines." In other words, we are taught to think in a linear manner, while they are taught to think spatially.\footnote{Wendy Richmond, "Promoting Visual Thinking", Communication Arts, August 2001, p. 186}
APPENDIX 6

TOLERANCE FOR AMBIGUITY TEST

Please respond to the following statements by indicating the extent to which you agree or disagree with them. Fill in the blanks with the number from the rating scale that best represents your evaluation of the item.

1. An expert who doesn't come up with a definite answer probably doesn't know too much.
   - Strongly Agree
   - Moderately Agree
   - Slightly Agree
   - Neither Agree Nor Disagree
   - Slightly Disagree
   - Moderately Disagree
   - Strongly Disagree

2. I would like to live in a foreign country for a while.
   - Strongly Agree
   - Moderately Agree
   - Slightly Agree
   - Neither Agree Nor Disagree
   - Slightly Disagree
   - Moderately Disagree
   - Strongly Disagree

3. There is really no such thing as a problem that can't be solved.
   - Strongly Agree
   - Moderately Agree
   - Slightly Agree
   - Neither Agree Nor Disagree
   - Slightly Disagree
   - Moderately Disagree
   - Strongly Disagree

4. People who fit their lives to a schedule probably miss most of the joy of living.
   - Strongly Agree
   - Moderately Agree
5. A good job is one where what is to be done and how it is to be done are always clear.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

6. It is more fun to tackle a complicated problem than to solve a simple one.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

7. In the long run it is possible to get more done by tackling small, simple problems rather than large and complicated ones.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

8. Often the most interesting and stimulating people are those who don't mind being different and original.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

9. What we are used to is always preferable to what is unfamiliar.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

10. People who insist upon a yes or no answer just don't know how complicated things really are.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

11. A person who leads an even, regular life in which few surprises or unexpected happenings arise really has a lot to be grateful for.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

12. Many of our most important decisions are based upon insufficient information.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree
13. I like parties where I know most of the people more than ones where all or most of the people are complete strangers.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

14. Teachers or supervisors who hand out vague assignments give one a chance to show initiative and originality.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

15. The sooner we all acquire similar values and ideals the better.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

16. A good teacher is one who makes you wonder about your way of looking at things.

- Strongly Agree
- Moderately Agree
- Slightly Agree
- Neither Agree Nor Disagree
- Slightly Disagree
- Moderately Disagree
- Strongly Disagree

\[85\] www.academic.dt.uh.edu/~averf.toler.html
REFERENCES


__________Standard Oil Company. *Creativity, the Human Resource*. Exhibit brochure.


