Creativity and Design in Technology & Engineering Education

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TABLE OF CONTENTS

Foreword ......................................................... iii
Yearbook Planning Committee ................................. iv
Officers of the Council ........................................ v
Yearbook Proposals ............................................ vi
Previously Published Yearbooks ......................... viii
Preface ........................................................ x
Acknowledgements ........................................... xi
Introduction ..................................................... xv
About the Authors ............................................ xvii

Section I: Properties and Relationships of Creativity and Design

Chapter 1: Providing the Context for Creativity and Design in Technology and Engineering Education 1
Scott A. Warner
Millersville University of Pennsylvania
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Chapter 2: Defining Creativity and Design 32
Barry Yatt
The Catholic University of America
Washington, District of Columbia

Joseph McCade
Millersville University of Pennsylvania
Millersville, Pennsylvania

Chapter 3: The Many Forms of Creative Expression 69
David R. Stricker
University of Wisconsin–Stout
Menomonie, Wisconsin

Section II: Human Capabilities for Creativity and Design

Chapter 4: Developmental Stages of Humans and Creativity 88
Gerald F. Day
University of Maryland Eastern Shore
Princess Anne, Maryland
Chapter 5: The Creative Brain

Kenneth M. Heilman
University of Florida
Gainesville, Florida

Chapter 6: Creativity, Innovation, and Design Thinking

Meredith Davis
North Carolina State University
Raleigh, North Carolina

Section III: Pedagogy and Environments for Creativity and Design

Chapter 7: The Knowledge and Skills of Creativity and Design

Todd Kelley
Purdue University
West Lafayette, Indiana

Martin Rayala
Kutztown University of Pennsylvania
Kutztown, Pennsylvania

Chapter 8: Physical Environments for Creativity and Design

Kerri L. Myers
Central Bucks School District
Warrington, Pennsylvania

Milton Shinberg
Shinberg.Levinas Architects
Bethesda, Maryland

Chapter 9: Cultural Environments for Creativity and Design

—A Case Study

Jennifer Baker
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Philadelphia, Pennsylvania

Chapter 10: Curriculum, Instruction, and Assessment for Creativity and Design

Gareth Hall
British School of Washington
Washington, District of Columbia
Section IV: Professional Development of Technology and Engineering Education Teachers

Chapter 11: Professional Development of Teachers to Support Creativity and Design in the Technology and Engineering Education Classroom 290

Marie Hoepfl
Appalachian State University
Boone, North Carolina

Chapter 12: Conceptual Framework and Perspectives for Creativity and Design in Technology and Engineering Education 321

Perry R. Gemmill
Millersville University of Pennsylvania
Millersville, Pennsylvania

Index 354
INTRODUCTION

The world is shrinking! The connectivity of communications is bringing us all together. No longer can we think of ourselves as members of a tribe, village, city or nation, but rather we are facing the dilemmas and opportunities of becoming citizens of the entire planet. In this expanded context, we look at ourselves and wonder about the role that we should play, how best to make a contribution and how to keep pace with constantly accelerating change. We realize that the implementation of another version of an accepted practice is no longer enough, but rather that we must learn to find something new, to change the framework and think in new and unexpected ways. Creativity and design must be added back into education to make this happen.

We must continue to teach young people in the best traditions of invention, engineering and science, to become expert innovators and rigorous thinkers, but at the same time we need to help them develop the subtleties of the arts, able to harness the power of intuition and lateral thinking, moving fluently from one side of the brain to the other. This is where creativity and design go hand in hand, as design and design thinking provide a bridge between logical and intuitive thinking, between objective and subjective, between the reasonable realm of explicit knowledge and the fuzzy soup of tacit understanding. Successful concepts mix creative “Ah a” moments of inspiration with careful analysis and structured development processes. This yearbook explains how to combine creativity and technology, teaching a future generation how to discover what needs to happen next as well as how to enable it.

Four themes inspire the scholarly contributions in the chapters that follow. The first helps us understand how creativity and design are inextricably intertwined, as design processes have evolved over centuries to enhance creativity through lateral thinking, conceptual blockbusting, intuitive problem solving, and subjective synthesis. The second theme looks at how the brain can achieve the partnership between logic and intuition, explaining how we develop into adults, the cognitive activities in the hemispheres of the brain, and the connections between innovation, creativity, and design thinking. The third theme looks at the physical and cultural conditions that are needed to educate successfully, showing that physical environments are important and that a culture that embraces qualitative attributes is essential. The fourth
theme is a call for action, looking at the ways and means of promoting creativity and design in technology education, as well as professional development for technology teachers.

This yearbook provides a guide and inspiration to help a new generation find a creative and sustainable place in a high technology and socially connected planet.

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We humans use creativity and design to solve a wide variety of challenges. From artist to artisan, from engineer to photographer, people create solutions that involve intuition and reason to varying degrees. Over the past century those who employ creativity and design have become increasingly specialized but perhaps more importantly, have found their ability to design to be increasingly valuable for solving contemporary complex problems in a comprehensive and imaginative way. While the artist, artisan, and engineer approach the creative process from different perspectives, they share common themes. Students can certainly benefit from learning about the similarities and differences among the various approaches to creativity and design. In fact, a general approach to creativity and design can be considered an important tool for everyone.

DEFINING TERMS

The purpose of this chapter is to provide the reader with working definitions and elaborations of key concepts. These definitions should be helpful toward providing a better understanding of the relationships among these concepts and the teaching of technology. The first definitions will deal with the contexts of technology and engineering. The rest of the chapter will define and expand on the concepts of creativity, design, art, craft, and other related terms.

Technology and Engineering. The relationship between technology and design (both architectural and engineering) is one that is so tightly bound together that it could be described as symbiotic.
Pearson and Young (2002) defined technology as “the process by which humans modify nature to meet their needs and wants” (p. 13). DeVore’s (1980) earlier definition of technology provided elaboration by stating that technology is “the creation and utilization of adaptive systems including tools, machines, materials, techniques and technical means and the relation of the behavior of these elements and systems to human beings, society and the civilization process” (p. 4). For most of human history the processes of developing and refining technologies were acts of trial and error, keen observation of natural phenomena, and serendipity. Harrisberger (1982) stated:

“Early technical progress in engineering was almost totally accidental. There was no rationale and no fundamental knowledge of nature. People continued to reconstruct these fortuitous accidents methodically and exactly throughout the years in order to preserve the results that were stumbled upon. (p. 5)

From the perspective of our current place in history, “Engineers are the professionals who are most closely associated with technology” (ITEA, 2000, p. 23). What distinguishes most of the technological developments of the modern world from those of the past is the involvement of engineering in the process. Petroski (1992) cited an official definition of civil engineering used by the American Society of Civil Engineers to identify what all forms of engineering specifically brings into the process of technological development. That definition stated:

“Civil engineering is the profession in which a knowledge of the mathematical and physical sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well-being of mankind in creating, improving and protecting the environment, in providing facilities for community living, industry and transportation, and in providing structures for the use of mankind. (p. 210)

From this perspective, engineering makes the process of technological development a purposeful, informed, designed act of technological creation.

Creativity. Creativity is one of those terms with many meanings. Treffinger, Young, Selby, Shepardson, and Center for Creative Learning Sarasota, Florida (2002, December) identified previous literature reviews that produced a substantial number of definitions for creativity. Their reasoning for why the literature produced over 100 definitions for
Defining Creativity and Design

this word is because “creativity is complex and multi-faceted in nature” (p. 5). To showcase the variety of definitions they provided samplings of definitions for creativity from 14 noted writers/researchers on this subject (see Table 1). A review of the definitions in Table 1 shows that they can be segregated into two broad categories: definitions that look at the behavior, actions, or characteristics of the person performing the creative act or the end product or outcome of the creative act. Tardiff and Sternberg’s (1988) view of creativity as being processes, persons, products, and places, or as problem domains and socially organized fields of enterprise is complementary of the findings of Treffinger et al. on the variety of definitions for creativity. Mayer’s (1999) identification of originality and usefulness as key attributes of creativity provides further focus on the unique nature of what is produced, which can be either an artifact or an idea.

Table 1. Sample Definitions of Creativity

<table>
<thead>
<tr>
<th>Sample Definitions</th>
<th>Emphasis in Definition</th>
<th>Primary Focus</th>
<th>Implications for Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fromm, Khaten, MacKinnon</td>
<td>Person</td>
<td>Characteristics of highly creative people</td>
<td>Assessment of creative personality traits</td>
</tr>
<tr>
<td>Gordon, Guilford, Mednick, Torrance, Treffinger et al., Wallas</td>
<td>Cognitive process or operations</td>
<td>Skills involved in creative thinking or in solving complex problems</td>
<td>Testing for specific creative thinking and problem solving aptitudes or skills</td>
</tr>
<tr>
<td>Maslow, Rogers</td>
<td>Lifestyle or personal development</td>
<td>Self-confidence, personal health and growth; self-actualization; creative context or setting</td>
<td>Assessing personal adjustment, health, and self-image; assessing the climate that nurtures or inhibits creativity</td>
</tr>
<tr>
<td>Gardner, Khatena</td>
<td>Product</td>
<td>Results, outcomes, or creative accomplishments</td>
<td>Assessing and evaluating products or demonstrated accomplishments</td>
</tr>
<tr>
<td>Amabile, Rhodes</td>
<td>Interaction among person, process, situation, and outcomes</td>
<td>Multiple factors within specific contexts or tasks</td>
<td>Assessing multiple dimensions in a profile, with various tools</td>
</tr>
</tbody>
</table>

Looking at creativity from another perspective, Csikszentmihalyi (1996) placed it within the context of a systems model, a context that should be familiar to the typical technology educator. Csikszentmihalyi’s description of this systems model perspective on creativity was as follows:

Creativity can be observed only in the interrelations of a system made up of three main parts. The first of these is the domain, which consists of a set of symbolic rules and procedures. Mathematics is a domain. . . . Domains are in turn nested in what we usually call culture, or the symbolic knowledge shared by a particular society.…

The second component of creativity is the field, which includes all the individuals who act as gatekeepers to the domain. It is their job to decide whether a new idea or product should be included in the domain. . . .

Finally, the third component of the creative system is the individual person. Creativity occurs when a person, using the symbols of a given domain such as music, engineering, business, or mathematics, has a new idea or sees a new pattern, and when this novelty is selected by the appropriate field for inclusion into the relevant domain. . . .

So the definition that follows from this perspective is: Creativity is any act, idea, or product that changes an existing domain, or that transforms an existing domain into a new one. And the definition of a creative person is: someone whose thoughts or actions change a domain, or establish a new domain. (pp. 27-28)

Regardless of which of the many definitions of creativity we choose to accept as our own, we all face challenges that inspire us to find solutions through the process of invention or that prod us to address the challenge through other creative expressions. It helps to think of what we do when facing such challenges as a response rather than an answer or a solution. This approach has several advantages. A response is broader than a product or artifact. For example, some responses do not involve tangibles but might be processes. Those who face challenges more imaginatively, who think “outside the box” tend to come up with better responses. Creative problem solving is critical to any game plan, whether done by a CEO in response to a business challenge, a division commander in response to a military push, an industrial engineer in response to a manufacturing challenge, or an architect in response to a housing need (von Oech, 1998).
Defining Creativity and Design

Words like artist and genius carry heavy baggage. Those characterized as such are often seen in society as constituting an elite fraternity, even a secret cabal, of gifted individuals whose creations may or may not be understood, but either way are not to be questioned by those less enlightened people from outside the fraternity. Such people are generally admired for their creativity, their ability to come up with innovative responses to challenges major and minor. But, they are also often seen as people who are a little strange, who just do not think the way the rest of us do (Boden, 1991; Kneller, 1965; Pinker, 1997).

But how do they do it? Where does creativity come from? Does one have to be born with the ability? Can people create even when they are not particularly creative (at least so far as they know)? Creative work is often described as a sort of “black box” process that those who use it often profess not to understand. Some equate process with logic, and thus think that identifying a process will override its intuitive component, thereby destroying its power. While this fear is misplaced, it leads the rest of us to assume that we cannot do that thing that they do so well – come up with creative solutions to functional problems – to “think outside the box”.

There is an interesting difference between traditional concepts of intelligence, normally associated with convergent thinking, and creativity, which is normally associated with divergent thinking; creative people manage to come up with multiple solutions where others fail to see even one (Gardner, 1993). Motivated by his own interest and experience with art, Gardner explored creativity in his book Creating Minds by examining seven creative individuals. Anyone aware of his theories about intelligence would not be surprised to learn that he concluded that creativity has many facets and can find its expression in many ways, certainly not just through art.

In the final chapter of the book The Nature of Creativity Tardif and Sternberg (1988) summarized the findings from the various chapter authors, all leading experts on creativity. They concluded that the creative thought process involves

- time (i.e., even if the creative process is thought to arguably involve a single flash of insight, a gestation process follows that involves refinement);
- transformation of external world and internal representations by forming analogies and bridging conceptual gaps;
- constant redefining of the problem;
- applying recurring themes and recognizing patterns and images of wide scope to make the new familiar and the old new;
- non-verbal modes of thinking; and
- tension between tradition and breaking new ground, the tension of having several competing ideas, and the battle between unorganized chaos and the drive to higher levels of organization.

Expressions of creativity can be broadly categorized as being either abstract or applied in nature. Abstract creativity results in self-expression that is usually described as artistic. However, technology education is more concerned with applied creativity. Applied creativity is defined by its effects on the natural and human made environments and gauged by the impacts it has on the uniqueness, efficacy, and variety of the solutions it generates.

Creativity is like a muscle that can be strengthened and developed. A designer can begin the process of generating responses (i.e., developing solutions) with only a rudimentary understanding of the challenge. However, he or she can also use the design process to get to a more complete understanding of the challenge. The designer can also wait until the challenge is fairly well explored through logic before starting to apply creativity. Regardless of which approach is used, this process of generating alternative responses is generally referred to as brainstorming.

Brainstorming gives us a way to increase the odds of finding inspiration. Inspiration may be provided by divine intervention, but generally, and especially with practice, can be provided by and traced back to some factoid or observation or recognition that was noticed, on some level, during fact-gathering, during the logical, left-brained part of the design cycle. Sometimes a designer will come up with an idea and not realize where it came from at first, only to recognize its source later on as something he or she originally noticed while visiting a project site or in talking to a projects’ future users or in something glanced in a magazine the weekend before. It may come across as inspiration for any of several reasons. The underlying or triggering fact may have been noticed only peripherally and may not have even registered consciously at the time it was gathered. Or it may have registered consciously, but with little or no sense of how it might be related to the problem at hand. Or it might have registered consciously, with some sense of how it
Defining Creativity and Design

might inform a solution, but without much of an idea of how it could be integrated with other factors in developing a complete, holistic, integrated solution.

Regardless of where the idea came from, it came from somewhere. The critical point is that it found its way into at least one proposed response – it was put on the table for consideration. And except for occasional and unintended moments of inspiration, what got it on the table was the process of brainstorming. Those who are not experienced in the design process (including “designers” who do not understand how they do what they do, but manage to do it without consciously using a design process) may not brainstorm or may not recognize their brainstorming efforts for what they are, and therefore tend to see all good ideas as being rooted in inspiration. Brainstorming is not critical, but without it there are far fewer options to work with. And with fewer options, it is less likely that an ideal one will emerge.

So how do designers use brainstorming to supplement or even to generate inspiration? They do so by letting go, by looking beyond the immediate goal of trying to solve problems. Being creative starts with opening one’s mind. Often, the best answer is not immediately seen as an outgrowth of the problem, but is seen as only tangentially or indirectly related. So it is critical to “think outside the box” to look beyond responses that are clearly in the realm of possible solutions. One needs to step back from the immediate task, to be non-judgmental as well as inefficient, in the short term at least. Brainstorming demands a willingness to:

- make mistakes on the way to a good solution.
- delay solving a problem while considering multiple alternatives.
- accept that although being creative is fun, when used this way it is a very serious undertaking.

In addition, it requires an understanding that creativity is only part of the design process, which requires alternate use of left (logical) and right (intuitive) brained thinking, with transition periods as needed in between.

The generation of many ideas to solve a problem is as old as human ingenuity. However, the process of brainstorming was named and formally structured by Alex Osborn. Osborn (1953), who was an advertising executive in search of a technique for developing lots of ideas, first started using “organized ideation” (p. 80) as early as 1938.
Though commonly thought of as a group activity, Osborn advocated the use of the brainstorming approach for both individual and group ideation. The basic rules for brainstorming that Osborn identified were

1. **Criticism is ruled out.** Adverse judgment of ideas must be withheld until later.
2. **“Free-wheeling” is welcomed.** The wilder the idea, the better; it is easier to tame down than to think up.
3. **Quantity is wanted.** The greater the number of ideas, the more the likelihood of winners.
4. **Combination and improvement are sought.** In addition to contributing ideas of their own, participants should suggest how ideas of others can be turned into better ideas; or how two or more ideas can be joined into still another idea. (p. 84)

Further guidelines advocated by Osborn (1953) for running a successful group brainstorming session included the ideal group size of 12 participants (p. 87), group brainstorming is a supplement of the individual brainstorming process (p. 80), there needs to be a written “reportorial” list made of the ideals generated (pp. 84-85), and an appropriately trained group leader who would facilitate the brainstorming session (p. 237).

Since 1958 there has been a great deal of controversy over the effectiveness of brainstorming as a technique for having a group of people generate lots of creative ideas. The original source of this controversy was a study completed at Yale University (Taylor, Berry, & Block, 1958) that asked the question “does group participation when using brainstorming facilitate or inhibit creative thinking” (p. 23). Unfortunately, as Vehar (2010) indicated, the results from the Yale study have been repeatedly misinterpreted to mean that brainstorming across the board does not work. Vehar summarized the problems of the original Yale study and the misinterpretation of what constitutes brainstorming by stating

[Over the years] several studies [have] use[d] the same misguided approach that the Yale study did, which is to say that they don’t use a trained facilitator to direct the group. Brainstorming is a specific tool with specific guidelines (defer judgment, etc.) that are enforced by a facilitator who guides the group’s thinking.

What many people mistakenly call “brainstorming” is in fact just “a bunch of people sitting around firing off and shooting down
Defining Creativity and Design

ideas.” Let’s call that “skeet-shooting.” And on that we can agree: working individually will work better than skeet-shooting in a group. (para. 8-9)

Beyond the mechanics of the process and the controversy, brainstorming is the task of generating, without judgment, copious alternatives from subconscious knowledge (i.e., information known at an intuitive level). It is the fundamental basis of creativity, open and free. The goal of brainstorming is to push the limits, to ask nothing, but just to generate. One could interrupt the process of brainstorming by asking “does this make sense,” but that would interrupt its flow, impairing its effectiveness, so one leaves that question to be asked later. Logically, there may be lots of reasons “why not” that can censor creativity and lead to the rejection of a potential solution before it has had a chance to be truly considered. Often, what so clearly seemed infeasible or problematic turns out, upon more careful examination, to be quite feasible. For these reasons, even subconscious judgment of ideas during brainstorming is counterproductive.

As an example of individual brainstorming, the sketches shown in Figure 1 (next page) represent one page containing forty alternative site plans generated by an architecture student exploring different ways to configure a new building on an existing site (Vanderdray, 2006). She kept going until she had filled eight pages with about two hundred options in less than an hour. Every alternative was feasible to the extent that it represented a building of about the right floor area and fit within the confines of the block.

But given those two key parameters, which could easily be understood at an intuitive level, anything that complied with them was worth a look. Were angled walls worth considering? Yes, as were curved walls or walls of any other shape. Were both symmetrical solutions worth considering? Yes, as were asymmetrical solutions, simple and complex solutions, and balanced and unbalanced solutions.
Figure 1. Tapping the Subconscious Through Brainstorming


Notice in this example how each sketch used only a few lines, supplemented with a few words serving to capture the basic idea for later on, when the student returned to evaluate and select the stronger
choices from among her many options. This brevity of notation allowed the ideas to be recorded almost as fast as they were imagined, so that the brainstorming mind was made available again very quickly to generate more ideas rather than lingering on any one idea. Will any one of these two hundred ideas be the seed of genius from which a great design will come? There is no guarantee, but certainly the odds of that being true is far greater than it would have been if only ten ideas had been generated.

In another example, it is often said that great wedding albums are the result of not only a photographer with a great eye, but also of a photographer who takes a lot of photos. It is doubtless true that one can make a far better forty-photo wedding album from five thousand images than from three hundred. And a photographer who hesitates too much, who thinks for too long about whether a particular shot is worth taking, puts intellect above intuition, risks losing the opportunity to get a particular shot. This caveat is not to suggest that good photographers randomly press the shutter. Rather, they use their intuitive understanding of the elements of a good photo to manipulate the interaction of the events taking place, their position, the lighting, and the composition in the viewfinder to raise the odds that any photo they take will be a quality image. But, they do their choosing and editing after the event is over, once they have finished creating and start editing.

Individual brainstorming has many of the characteristics of play. Stuart Brown (2009) identified the properties of play as

- Apparently purposeless (done for its own sake),
- Voluntary,
- Inherent attraction,
- Freedom from time,
- Diminished consciousness of self [an “in the zone” experience],
- Improvisational potential [for thinking and doing], and
- Continuation desire [toward the experience] (pp. 16-18).

Like play, brainstorming is best done with toys rather than words or numbers. When in this mode, designers act, they do, rather than talk or write. There is something about movement, about action, that allows things we know subconsciously to express themselves. This phenomenon is why architects learn to trust their hands. Sometimes, architects will just start drawing, and in doing so, find that their hands document design alternatives that their minds did not consciously know they were thinking. Artists will often play with clay or paint or stone just to prime their ability to generate inspiration. Mechanics might just start arranging or cutting or assembling parts with no fixed idea of what
they are trying to get out of the process. Athletes and dancers can use bodily movement to help them brainstorm. Musicians can hum, sing, or play instruments to help them.

To the extent that someone using the design process can figure out, on a conscious level, the subconscious information that led to his or her insight, so much the better. That knowledge can make it easier in the future to repeat the feat of “inspiration at will”, and at least helps to satisfy what otherwise may be a gnawing uncertainty about whether brainstormed ideas are based in valid issues and legitimate knowledge.

Note that for the subconscious mind to use the information it “knows,” that information needs to be known to the subconscious. If it was initially received or registered there, all is fine. But if a student first becomes aware of an important factor on a conscious or intellectual level, as the result of fact gathering or experimentation, it needs to be “forgotten”, to be registered in the subconscious. As mentioned above, achieving this movement is one of the critical roles of the transition time inserted between cycles of logic and intuition.

So is creativity simply the product of a large number of alternatives informed by intuition? What about artistry? What about inspiration? While it is true that bolts of inspiration can sometimes strike, odds are greatly increased if one takes the time to increase the field of possibilities through brainstorming. If a truly inspiring solution is not among the ones being considered, it cannot be selected.

And what of the idea of creativity restrained only by some intuitive understanding of the goals, without intellectual constraints? What is the point of generating options that in the end will prove to be “bad ideas?” Is that not an inefficient use of time? Designers will respond that it is actually a very efficient use of time, because it is far more expeditious to unbundle idea generation from idea evaluation than to try to do them simultaneously. Brainstorming is a very powerful exercise, and left free to do its work, is so efficient in generating alternatives that one can afford to throw most of the ideas in the scrap heap before one would have to worry about using time inefficiently.

It is also critically important to feed the intuition before starting to brainstorm, or the alternatives generated will be meaningless. This might be thought of as “stoking” the process. Stoking involves gathering information, analyzing it, and extracting the implications of the analysis for the challenge at hand. Once this is done, it must be moved from the conscious mind to the subconscious, to influence
Defining Creativity and Design

brainstorming in an unselfconscious way. We will come back to this idea later, after we finish exploring creativity and brainstorming.

How can the creative side be freed to do its work? It requires letting go of the intellect, of being willing to suspend being “responsible” and “focused”. For Americans, perhaps the difficulty is related to having frontier and Puritan roots. Creativity is closely related to play, and we tend to do less of both as we get older, as we grow up. But this idea of play, truth be told, is what drives designers in their passion for what they do. Allowing the brain to run at full throttle, without restraint, without thinking “oh, that won’t work or that’s dumb” is incredibly addictive. But most of us have never experienced that rush, because we cannot stop being practical, cannot stop thinking about what “can” and “cannot” work. But it is only when we do allow ourselves to forget, that we unleash the full power of our minds, though the power of creativity when used as part of the design process.

Eventually one must ask, “does this make sense?” Once a list of response alternatives is generated it must usually be edited down to a single response since usually only one response can be implemented. To do that, the positive and negative evidence regarding the advantages and disadvantages of potential responses must be applied to the alternatives that were generated at the subconscious level. This requires that the alternative solutions be documented, be made tangible, so they can be recalled and assessed once the brain has emerged from its intuitive mode and, to some extent, forgotten some aspects of the full idea that had been envisioned. Concepts can be made tangible with a few short scribbled notes, through sketches, models, simulations, or with any number of other means of representation or expression, many of which are seen as evidence of creativity, even though they are really only but one step along the process of design.

Design. Creativity, as discussed, is an essential element in the overall process of design. Though the word design can be both a noun and a verb, this chapter focuses on design as a verb. This focus is intentional because, ideally, technology education uses the end product of the design process (a noun), as simply a means to teaching students how to do the process (a verb). The American Heritage Dictionary of the English Language defined design as a verb: “to formulate a plan for; devise” (Design, 2009). The focus in this chapter is more about teaching people how to design rather than what to design. Fundamentally, design is one of several processes people can use when making decisions. Design harnesses both intellect and intuition to solve challenges too
complex to be solved by either one alone. The ability of the design process to work when addressing highly complex challenges is what informs it as a process, and what makes it so versatile and relevant to contemporary problems in this era of globalization. The key, defining characteristic of design is the fact that designers think holistically, using both the left and right sides of their brain. Design combines creative elements and processes, such as brainstorming, with evaluative editing in repeated cycles to get increasingly close to an ideal solution, especially when stoked occasionally with supplemental information.

**Design and Technology.** Design is categorized as both a part of technology and a broader unifying theme for multidisciplinary education. The British were leaders in the adoption of design as a fundamental part of technology education. In the 1980s, curriculum development efforts eventually resulted in the creation of three textbooks for craft, design, and technology (CDT). One of them, *Design and Realisation* contained this explanation of design:

Designing is an activity which uses a wide range of experiences, knowledge, and skills to find the best solution to a problem, within certain constraints.

Designing is a creative activity. You may often use known facts or solutions, but the way to combine these to solve your own particular problem requires creative thinking.

Design is far more than just problem solving. It involves whole process of producing a solution from conception to evaluation. This includes elements such as cost, appearance, styling, fashion and manufacture (Breckon, 1988, p. 2).

In 1994, Americans Hutchinson and Karsnitz offered a straightforward definition of design:

Design is *the planned process of change.* Instead of something changing by accident, design demands that we change so that we end up with the results we want. It also means that we attempt to minimize trade-offs and control risk. Technology is all about design. (p. 18)

The International Technology Education Association (2000) made a critical contribution to the field by identifying design as an essential underpinning of technology. “Design is regarded by many as the core technological problem-solving process of technological development. It is as fundamental to technology as inquiry is to science and reading is to language arts (p. 90).
Defining Creativity and Design

**Design as a Process.** Breitenberg (2003) described design as more than a tool used by various practitioners but as a discipline in its own right. He reveals his belief in the interdisciplinary nature of the design discipline in recounting the accomplishments of Raymond Loewy who “was trained as a fashion illustrator, designed a steam engine, a greyhound bus and a Studebaker, the packaging for Lucky Strikes, food and soft drinks, to name the most prominent. And he’s just as well known for his marketing skill...” (p. 8). Just as the arts have rhetoric and inquiry and the sciences have the scientific method, technology has design. And although the discipline of design draws on arts and sciences, it also has its own body of knowledge. Cross (2007) stated it this way: “Design has its own distinct’ things to know, ways of knowing them, and way of finding out about them (p. 17). Design can become the **anchor**, the **common theme**, and the **driving force** in helping learners experience technology. Like art and science, design is a way of responding to a challenge. When confronted with a problem, a scientist might establish a hypothesis, conduct an experiment, gather data, assess it, and then try to respond to the problem. Someone in the arts might instead review arguments made by others faced with the same challenge, develop his or her own conclusions, posit a position, and then express it as a creative work (literary, performance, culinary, etc.). In both cases:

- The process used is generally either right or left brained but not both.
- The process is generally linear.
- There is generally significant focus on the response, the “answer” or the “creative work”.
- The data or ideas that inform the response are often verifiable or can be known.

In contrast to an artist or scientist, a designer confronted with a problem might conduct an iterative series of explorations and ventures, alternatively using intellectual and intuitive modes. The explorations involve observing and assessing, and the ventures involve the brainstorming of possible responses. The two modes are repeated, with the designer increasingly refining the proposed response. The process alternates between left brained and right brained, but they are not used simultaneously.

- The process is iterative, repeated multiple times, each time coming closer to satisfying the challenge.
- The data that inform the response are often complex, interrelated,
subtle, subjective, elusive, and often change while the design is being pursued.

Logic and intuition can often work together on a subconscious level to solve a problem. After collecting significant amounts of data about a problem, logic alone is often insufficient to integrate all the diverse considerations and come up with an elegant solution. This phenomenon is why one must sometimes “step away” from the problem to give the subconscious, intuitive side a crack at the problem. Trying to solve a complex problem with intuition alone is seldom effective, because collecting information and grouping it logically is usually a prerequisite to the effective application of intuition. The subconscious nature of intuition helps explain why expert problem solvers often find it difficult to express exactly how they came to their creative solutions.

According to Yatt (2010), design is its own discipline with its own set of mental processes and outcomes. He expressed his perspective on these issues when he wrote

Design merits being classified as its own discipline not by virtue of the fact that it produces a different product than science or art. In fact, no particular product is a necessary outcome of the discipline of design, what distinguishes design is the nature of its process. The arts tend to be right brained—their bodies of knowledge are expressive and their processes are intuitive. The sciences tend to be left brained—their bodies of knowledge are empirical and their processes are logical. By contrast, design is both right and left brained; its bodies of knowledge that are both expressive and empirical, and its processes are both intuitive and logical. One might, in fact, reasonably define design as the discipline of comprehensive, or holistic, thinking. In fact, both artists and scientists are likely to engage in design at some point as they follow their respective disciplines. (p. 4)

Yatt (2010) wrote in another section that

Design is a discipline that makes it possible to respond in a creative, imaginative, and holistic way to a complex mix of seemingly unrelated concerns and issues. Although we often describe designers as people who ‘think outside the box’, one might far more accurately describe true designers… as those who harness insight to enable them to push the limits of the box. It isn’t possible to think outside the box without fully and deeply understanding the edges of the box and all it defines and contains. (p. 4)
Defining Creativity and Design

What if average people could develop the kind of outside-the-box creativity that distinguishes architects and inventors, and use it to develop insightful responses to the challenges that arise in their own lives? Using creativity, every human being can learn to think outside the box to some degree, to begin to draw on intuition as well as intellect, their rational side and their intuition to think up creatively appropriate solutions to difficult problems. Drawing solely on the objective left hemisphere of the brain is just as limiting and ultimately ineffective as drawing solely on the subjective right hemisphere of the brain. In other words, neither the accountant nor the artist in each of us alone can do the job completely when the challenge is too complex for either hemisphere to handle it alone. Often it is the intuitive right brain that comes into play when generating a wide range of responses, even if it is the logical left brain that vets these ideas and applies to them the details that make them reality (Pink, 2006). Imagination can sometimes do its best work in the subconscious. Sometimes sleeping on a problem is the best advice, as it gives the intellect a rest, allowing the subconscious a chance to operate and play its essential role in problem solving. We often awake to insights, because creativity is encouraged when a little cognitive distance is gained (Barrett, 2001; Goleman, Kaufman, & Ray, 1992).

Kneller (1965, pp. 47-57) identified a five-stage model describing the creative process (see Figure 2 next page).
First insight
formation of problem

Preparation
conscious attempt at solution

Incubation
no conscious effort

Illumination
sudden emergence of idea

Verification
conscious development

Figure 2. Kneller’s Creative Process Model


1. First insight involves the identification and clarification of the problem or challenge.
2. Preparation is the research stage. As the designer gathers data he or she will often revisit the first insight stage and redefine the challenge.
3. Incubation occurs when the rational, left hemisphere of the brain disengages allowing the intuitive right hemisphere to process complex variables. As shown by Figure 2, this stage best occurs in the subconscious. Lawson (1997) illustrated this point in describing the work of James Watson and Francis Crick who discovered the double helix shape of DNA, “The structure of DNA as we know it today simply could not be logically deduced from the evidence available to Watson and Crick. They had to make a leap into the unknown, a demonstration of divergent thought par excellence!” (p. 156) Incubation is important in approaching design as a creative process, as opposed to solely a problem solving process.
4. Illumination occurs when the mind has reorganized and prioritized the information gathered in the preparation stage and a solution become apparent.
Defining Creativity and Design

5. **Verification** includes testing, refining and developing the idea to fulfill the final stage of the creative process.

Our experiences with architectural design and design education suggest the need for modifications to Kneller’s model, resulting in a more fluid approach to design. The following points are of note:

- The Kneller model started with problem definition (i.e., first insight). This beginning stage is efficient, because generating alternative responses before understanding the challenge can be a waste of time. For some, it is a necessary first step toward bringing one’s creative abilities into the process of creating a response to the challenge. However, starting with problem definition may not suit the personalities of all designers. Because design is an iterative process wherein the designer cycles through the steps multiple times, where one starts may be less critical than finding and using a process that works.

- Once the problem is defined, the Kneller model goes right to preparation, a conscious attempt at solving the problem. We have observed that there is danger in trying to go too quickly to solving a problem, and would stress the importance of exploring it first before making any focused attempt to solve it. We suggest that going to incubation, where brainstorming happens, before preparation, is a more productive order for these two steps.

- Note that incubation involves a lot of effort, even if it is not conscious. Brainstorming should be exhaustive and can be exhausting.

- Illumination is not really a stage, and it generally does not happen suddenly. It happens when it happens, and like the process as a whole, it happens multiple times, at multiple levels, at multiple points along the way.

Figure 3 (next page) describes a model for design that uses both the left and right hemispheres of the brain. Instead of linear, it is circular. It repeats until the designer or design team runs out of time, interest, or energy, or whenever they decide that the solution is good enough. Its elements are

- stoking (left-hemisphere data gathering, analysis, and application)
- transitioning (from left- to right-hemisphere mode)
- brainstorming alternatives (right-hemisphere)
- editing options to cull weaker ones (left-hemisphere)
- repeat
While brainstorming was already explored in the section on creativity, the other three have not been. In each iteration of the design process brainstorming eventually reaches a tentative conclusion. This completion happens when the well of creativity has divulged all it can without additional input. It is the time to sort through all of the alternatives and evaluate them. This is a time of questioning, largely of comparing the alternatives generated with the project’s goals to figure out which alternatives respond most effectively and comprehensively to those goals. In the end, only those alternatives should remain that have
strong potential to address the problem. It may not be clear yet which is the best, and it is very likely that all of them could use further refinement. But before doing further editing, and so long as time remains, one will likely want to get more information to use in generating yet more alternatives, more sophisticated and nuanced alternatives, from those that remain. We will now look at stoking, which is the process of gathering and assessing information, as well as transitioning.

**Stoking.** In the design professions the process of doing preparation for responding to a challenge is known as stoking (Yatt, 2001, 2008). One effective technique for stoking involves five steps that form the acronym AGENT (see Figure 4):

1. Ask questions
2. Gather information
3. Enhance the information to make patterns
4. Notice the implications of the patterns
5. Translate the implications into design options (Yatt, 2010)

**Figure 4.** The “AGENT” Design Stoking Model

The two steps most unique to the design process are enhancing and noticing. The two are often simply referred to as analysis, but for design, using processes that engage the subconscious helps the analysis.

Analysis, while primarily intellectual, is not necessarily at its most effective when it is limited to poring over statistics and written data. We often recognize data patterns most effectively when they are presented in a form that registers subconsciously. But what kind of information registers subconsciously? Patterns in data that are presented

-52-
as drawn (2D), modeled (3D), or animated (4D) graphic representation of words and numbers are often far more easily recognized on a “gut” level. How much faster and more accurate is a response to a graph than to a table of statistics, even though they both document the same set of data?

As an example, consider the following: An architecture student, who is asked to design an elementary school, wonders where to locate the entrance. The student gets data on the forms of transportation used by different groups of users, thinking that it would make sense to put the entrance on the side of the building at which people would be arriving.

The architecture student finds that for students, 45% walk, 20% come by car, another 25% use the bus, and the remaining 10% come by the Metro system (the subway). The architecture student gets similar data for the teachers and staff, but the findings are seen just a bunch of numbers. This situation lends itself, perhaps, to intellectual comprehension, but not so much to intuitive comprehension. So, since the architecture student wants to be able to draw conclusions easily, it is decided to arrange the data in a table, as shown in Figure 5.

**Figure 5. Table with Numbers**

<table>
<thead>
<tr>
<th>Target Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
</tr>
<tr>
<td>Modes</td>
</tr>
<tr>
<td>Walk</td>
</tr>
<tr>
<td>Car</td>
</tr>
<tr>
<td>Bus</td>
</tr>
<tr>
<td>Metro</td>
</tr>
</tbody>
</table>


This is an improvement, but the student thinks the findings can make it even more expressive. The table showed relationships better than the plain numbers did, but the student knows it will work better as an analysis tool if the numbers are removed. So bars are substituted whose lengths correspond to the numbers, as shown in Figure 6.
Defining Creativity and Design

Figure 6. Table with Bars

<table>
<thead>
<tr>
<th>Modes</th>
<th>Target Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Students</td>
</tr>
<tr>
<td>Walk</td>
<td></td>
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<tr>
<td>Car</td>
<td></td>
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<tr>
<td>Bus</td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td></td>
</tr>
</tbody>
</table>


With this done, the architecture student is able to see patterns in the graphic arrangements of the data rather than have to make conceptual patterns with the numbers, a process that engages the intuition better. This helps the student see that each population used one form of transportation far more than the other two, but it was a different form for each group, as shown in Figure 7. Yes, this same information was there in the raw data, and in the table with the numbers, but it did not stand out as it does with the bars. As they say, a picture is worth a thousand words. The bars helped give a “gut” sense of what the numbers represented.

Figure 7. Recognizing Patterns

<table>
<thead>
<tr>
<th>Modes</th>
<th>Target Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Students</td>
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<td>Walk</td>
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<tr>
<td>Car</td>
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<tr>
<td>Bus</td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td></td>
</tr>
</tbody>
</table>

This example shows how information can be digested into the subconscious. After using such techniques, a designer can return to brainstorming to see what further ideas might present themselves. This repeated cycle of problem stoking (insight), brainstorming (incubation), evaluating and editing (preparation), leading to (illumination), moving slowly but iteratively toward a strong response, is the essence of the design process.

**Transitioning.** Once information sufficient to answer the initial questions has been gathered, one can start to get creative. But before unleashing the right brain, a transition period is important, especially before proficiency in the design process is achieved, because thinking logically and thinking intuitively are so different. One cannot just jump from one mode to the other, at least not without a lot of practice. And, the two modes cannot be done at the same time since they inhibit each other. Brainstorming is limited and censored by logic. Logic’s careful order and sequence is interrupted and thrown off by brainstorming. Thus, good design work requires “serial schizophrenia”, where each half of the brain is put to work independently of, and without being distracted or confused by the other. Time and distraction are critical elements in winding down and shutting off the left-hemisphere in anticipation of powering up the right-hemisphere.

During this transition period, it is important to get distracted by something else, anything else, doing nothing related to the challenge. This time allows the brain to switch over from left hemisphere to right, from an ability to work intellectually to an ability to work intuitively. And just as critically, the transition time allows the gathered information to percolate down into the subconscious, where the right hemisphere can get access to it when brainstorming. This transition time can take two minutes or two weeks, and decreases with practice.

When the transition from logic to brainstorming mindset is finished, one can productively engage the right hemisphere. This repeated cycle of right and left hemispheric thinking, with transitions as needed and stoked with additional insights as necessary, is the essence of the design process.

**Art and Craft.** Historically, human knowledge and skills have become increasingly specialized. Burke (1978) argued that the start of that specialization began with the start of agriculture. The process would accelerate exponentially with the industrial revolutions of the 18th, 19th, and 20th centuries. However, art, craft, technology, and engineering, regardless of how specialized their knowledge and skills
Defining Creativity and Design

may have become, still share the common threads of creativity and the design process.

The terms art and craft carry many different connotations in many different contexts, especially as they relate to design and technology education. They also carry connotations in everyday use (e.g., artist versus craftsman, fine art versus applied art, patron of art versus customer for craft), but the current exploration will be more limited, focusing on the design context, where art and craft differ in their use of insight and the extent to which they benefit from the intuition. It is difficult to discuss one without the other, so they are treated here as a duality.

In spite of having an immediate history labeled industrial arts, technology education and its predecessor curriculums has generally focused more on craft than art. Yet it is easily argued that a craftsman can eventually become an artist. The masterpieces on display at the Musée des Campagnonages in Tours, France¹, are a perfect illustration of this idea. Campagnonages are guilds, and this museum is filled with demonstration projects in roofing, basket weaving, blacksmithing, saddle making, baking, and more. Some of these displays are hundreds of years old, made by journeymen proving their worth as master tradesmen (hence the term “masterpieces”). These works reflect the joy and imagination, as well as the diligence and mastery, of people steeped in their techniques and comfortable with experimentation, to the point that their craft has become second nature to them and they can become inventive beyond anything they learned from their masters.

The craftsman is trained to apply particular techniques to particular situations. For example, 1½ cups of water mixed with 4 cups of flour can make dough suitable for bread. When that combination is produced over and over again, eventually the baker starts noticing subtle differences. If the dough is made with slightly more or less water relative to flour, the dough behaves slightly differently, suggesting differences in the end product (e.g., bread, pizza crust, pasta) that could result. After learning, by experience or training, hundreds of subtle differences caused by water-flour ratio, and more hundreds of subtle differences caused by flours ground to different degrees of granularity, and even more hundreds caused by differences in the region where the flour’s grain was grown, sooner or later the possibilities become overwhelming. The master baker, therefore, stops depending solely on his left hemisphere, his storehouse of facts, when he bakes and starts also involving his right hemisphere, his intuition. It is again this
harnessing of both halves of the brain, this combination of knowing facts with a less tangible attitude of *je ne sais quoi* (literally *I do not know*), this mixing of techniques with hunches, of attention to detail with grand gestures, that is the essential difference between a craftsman and an artist.

It can easily be argued that one cannot set out to make art. Instead, art evolves naturally when mastery of individual technique has become sufficiently complete at the same time that a highly complex set of challenges is presenting itself for resolution. In this context, a craft is the product of skill; whereas, an art is the product of vision. A craft makes an undertaking do-able but an art makes it worth doing. A craft responds to a problem by making it functional, but an art responds by making it memorable. Without craft, art cannot be realized. Without art, craft fails to inspire reflection. This discussion all starts to smack of poetry, which leads to the next aspect of creativity: story.

**Story.** Pink (2006) believes that those people who are able to effectively apply the right hemispheres of their brains will rule in the new “conceptual age.” One of the six aptitudes that Pink advocated for successful participation in this conceptual age is story. “Stories are easy to remember—because in many ways, stories are how we remember (p. 99).” Turner (as cited in Pink, 2006) wrote “Narrative imagining—story—is the fundamental instrument of thought. Rational capacities depend on it. It is our chief means of looking into the future, of predicting, of planning, and of explaining...Most of our experiences, our knowledge, our thinking is organized as stories” (p.99). To Pink, “story is just as integral to the human experience as design” (p. 99).

Norman (Norman & Dunaeff, 1994) explained that story is both high-concept and high-touch:

Stories have the felicitous capacity of capturing exactly those elements that formal decision making methods leave out. Logic tries to generalize, to strip the decision making from the specific context, to remove it from subjective emotions. Stories capture the context, capture the emotions.... Stories are important cognitive events, for they encapsulate, into one compact package, information, knowledge, context, and emotion. (p. 146)

Story is perhaps the most important element in the design process. Story could also be thought of as plot, narrative, or path. It is the holistic vision and the handle by which the mind can retain a complicated set of data points. It is the key element in bringing the right half of the brain, where intuition resides, to bear on a challenge. Without story, only the
left half of the brain, where logic resides, tends to be harnessed. Without story, the myriad aspects of the challenge and the multiple alternatives that a designer brainstorms in response, are just so many equally compelling options. And too many aspects and alternatives tend to overwhelm “standard” thought processes.

Story makes ideas memorable and makes hopelessly complex amalgamations of elements able to be held by the human mind. It is what allows the human mind to see patterns, to simplify, and thus to wrap itself around what otherwise might simply be unrelated sets of terms, facts, images, or ideas. Story is a key element in bridging intellect and intuition so that they can work together in responding to challenges.

The sketch shown in Figure 8 (next page), from the design work of an architecture student, overlays a diagram on a map of a downtown area in an attempt to distill a story about movement. The three dotted circles indicate places that serve as circulation nodes, where people slow down and reorient themselves before proceeding. The dotted rectangle at the bottom indicates the presence of a waterfront area that is a common goal, a viewpoint if not an actual destination, an “end of the story”, for those in the area. The arrows attempt to show the way people might move through or past the site, the rectangle in the middle of the image between two of the circles. This diagram, and the act of drawing it, starts the mind thinking, starts to help the designer get an intuitive feel of the forces acting on the site, starts to tell the story.

Story is what led ancient mariners to see animals in rather random groupings of stars and even to name them as constellations. How much easier is it to understand the idea of navigating toward the “end of the little dipper’s handle” than to aim for what would be the 62nd star above the horizon if it’s July 18th at 9:27 in the evening? Story reduces a complex set of phenomena or elements or actions into basic ideas. And as challenges involve increasing numbers of elements, multiple sets of stories can be strung together into larger mental images that can be used to harness this complexity. Stories also tend to lead to other stories, suggesting further possible responses and more out-of-the-box thinking.
Figure 8. Sketching Over a Map as a Way to Think Through Possible Stories About Movement
Einstein came up with the theory of relativity after imagining himself “riding on a beam of light,” clearly an intuitive insight, even though he ultimately expressed his theory using logic, as the mathematical formula $E=MC^2$. Newton imagined gravity as an apple falling from a tree. Contemporary physicists talk about the even more complex “string theory”. Each of these happenings is an attempt to capture the complexity of a challenge or its solution as a simple story. Stories provide an anchor, a reference point, for managing all of the hundreds or thousands of facts and thoughts that comprise the entire scope of a challenge. Ultimately, the use of story tames problem-solving, thereby making the design process possible.

Story is the element that enables holistic understandings of complicated problems. With story, the design process can begin to work its magic, alternatively moving from the right hemisphere of the brain to left and back again, in one moment letting imagination manipulate elements while they are easily manipulated—compressed and expressed as stories—and then in another moment letting logic focus on, expand, and “drill down” into one or two elements within the overall story without the distraction posed by the other elements of the challenge, to ultimately manage to succeed in responding to a challenge’s otherwise overwhelming complexity.

THE ROLE OF CREATIVITY AND DESIGN IN TECHNOLOGY AND ENGINEERING EDUCATION

With these understandings of technology, engineering, creativity, design, art, craft, and story, one can start to look at their role in technology education. A challenge central to the mission of technology education is to prepare students to make critical choices about complex challenges created by technologies of ever increasing power. As this power exerts more and more leverage over our world; the stakes grow higher. These stakes require a decision making process not limited to either hemisphere of the brain.

The difference between responding to challenges driven primarily or exclusively by logic, and solving problems grounded in logic but fueled by creativity, helps explain the difference in the complexity of the situations each can manage and the elegance with which each can do
Creativity and design are critical to being holistic in such a way that other related problems are eliminated in the process. When bringing creativity and design into the classroom, there is the question of whether student work can be evaluated in an objective way. As mentioned earlier, creativity can be abstract or applied. Abstract creativity generally draws heavily on self-expression. It is usually primarily artistic in nature, making a statement and responding to emotional matters. Its “designs” can be very subjective, a matter of personal perspective or “taste”. Applied creativity, on the other hand, is concerned with responding to problems that are more often physical or logistical. Its solutions may well reflect the designer’s intuition and artistic flair but are intended to strike a balance between form and function, between responding to emotional and practical problems. This kind of creativity results in work that, to a large degree, can be judged against criteria that is external to the designer. Thus, it is possible to conclude that a student design is strong even when the instructor finds its aesthetic not to his or her liking.

A critical role of creativity and design in technology education is to help students develop more holistic, more flexible, more adaptive ways of thinking and responding to the increasingly complex problems encountered in contemporary situations, by adding the power of their brain’s right hemisphere to what they have already developed with their left hemisphere. The proper role of creativity and design in technology education is unlikely to manifest if design is taught as if it emerges from the combined perspectives of scientist and artist. That is because design (process) is not a hybrid of other processes, and effective designs (product) do not result from following any number of non-design processes, but rather result from following the unique process that is design. The fundamental definition of the design process, as creative problem solving, evokes an approach that demands both intuition and reason, not as separate approaches used in different disciplines but as a single holistic and multidisciplinary approach.

One measure of the status of creativity and design in technology education is the amount of discussion of these topics within the professional literature. Warner (2010) searched The Technology Teacher (TTT) and the Journal of Technology Education (JTE) in an attempt to determine the extent to which creativity and design have been recognized in technology education. He found a total of 350 TTT articles written between 1998 and 2008. Only three of their titles contained the words “creativity” or “creative.” For the same ten year
period, Warner found only three more articles containing those words in the JTE. Considering the importance of design in teaching technology the relative absence of scholarly work centering on creativity is of concern. At the very least, an exploration of the role of creativity in the design process is indicated. This is especially critical since technology educators tend to focus heavily if not exclusively on engineering. Of course, an emphasis on math and science does not and should not preclude an emphasis on creativity but rather almost demands it, despite what history suggests. Perhaps the best way to look at teaching design, the process of creative problem solving, is as a balancing act. The trick is to give students knowledge, skill, and experience without “mechanizing his or her thought process to the point of preventing the emergence of original ideas” (Lawson, 1997, p. 161).

**APPLYING CREATIVITY AND DESIGN TO TECHNOLOGY AND ENGINEERING EDUCATION**

According to Lawson (1997), “both convergent and divergent thought are needed by both the scientist and artist, it is probably the designer who needs the two skills in most equal proportions. (p. 156)

Too often, we fail to balance the rational and the intuitive in design instruction. As we have seen, responding to complex problems requires more than a singular, literally unilateral, approach based solely upon either right- or left-brained thinking.

The first step in applying right-brained thinking to technology education is getting students to feel comfortable with being creative and imaginative. We teach students, overtly and in subtle ways, that intuition is not to be taken seriously or even trusted, and that only logic is associated with maturity, intelligence, effectiveness, and reward. We essentially leave creativity behind with crayons and kindergarten except for those who tend to be marginalized or who self- marginalize as “creative types”. Creativity is often seen as superfluous, something for which the traditional business world has little time or patience. However, schools and society need to change these messages for the sake of addressing the complex issues we face, because for such challenges, the most efficient way to an optimal solution requires the seemingly inefficient design process, requires taking one’s eyes off of the challenge long enough to brainstorm, to imagine, the best response.
It is beyond the scope of this text to propose how creativity might be realized for our culture at large, but there might be ways that technology education programs could start, perhaps by teaching the idea of design as a process, one that alternately uses left- and right-hemisphere based approaches to problem solving to arrive at a response that neither alone could achieve. Since technology programs are generally more focused on teaching logical approaches than intuitive approaches to problem solving, we need to think about how, exactly, we might change that. Let us look at how stoking and brainstorming, and the design process as a whole, might actually be used in the classroom.

**Stoking in the Classroom.** As noted, the design approach starts like any logic process, generally but not always starting with the left-hemisphere gathering data that will inform the upcoming intuitive venture. Students can use any of a number of approaches to gather data including reading, interviewing, polling, measuring, experimenting, and testing, until they get information of sufficient quality and quantity to inform a response. The AGENT process can be a very effective way to prepare raw information so that it can inform brainstorming. Along with AGENT, it will likely be important to push students to use intuition in their analysis work, perhaps by asking them to translate the data they find into graphic form, to help them understand it on a gut level, or by having them play with the data until it works its way into their subconscious.

The critical element with information gathering is to take it far enough. Information is not gathered just for the sake of having information. Students too often think they are finished when they have a list of facts or a graphic expression of facts (e.g., a map). But until implications for design are extracted, these facts are of almost no use. Students must confront the “so what” question: “So what difference does it make to have found the information you found - how does it change your design options?” Only with the answers to those questions can one start to brainstorm.

**Brainstorming in the Classroom.** Remember that brainstorming has a lot to do with play. Its goal is to increase the number of alternative solutions, to create, where the goal of logic is to reduce them, to edit. Brainstorming is consciously unrestrained but subconsciously guided. This principle means that when brainstorming, students must consciously try to avoid thinking about why any particular solution might not work or might be inappropriate. During brainstorming,
Defining Creativity and Design

students come up with ideas that they did not know they had; thus, they are “inspired”.

Students often need to be pushed with regard to these attitudes. Going against the status quo can be difficult and in all likelihood young people will be using these attitudes in an educational or business system that discourages them. It takes time, perseverance, and patience on the part of the students. Instructors need to encourage brainstorming. Once creative work is temporarily done, once brainstorming has reached the limit of its store of creativity, once inspiration dries up, the entire process is sent back, for another spin of the cycle, to the more familiar left-hemisphere realm of logic.

For technology educators wanting their students to use both sides of their brains, starting to brainstorm might involve encouraging students to experiment, to simply explore a problem before solving it, to deeply understand a challenge before responding to it, to play, and to do so by doing rather than by talking or “thinking”. Remember that a critical rest period, distraction time, makes it possible for students to successfully turn off their intuitions and engage their intellects whenever necessary.

Ultimately, the point of teaching students to brainstorm is to get them to play with the realm of possible responses rather than looking only for the best response, to expand their thinking through brainstorming before contacting it through logic, through editing out the weaker alternatives. But weak alternatives cannot be edited out unless there are many to choose from, and generating many alternatives is the role of brainstorming.

Designing in the Classroom. Ultimately, there is no need to wait for inspiration. With practice, creativity can be made to happen by properly applying the design process. A holistic approach to design, one that teaches the learner to use both hemispheres of the brain, requires some resources, particular in terms of time and patience. It requires an intentional and ongoing effort to balance classroom experiences that engage both the left and right hemispheres. These types of experiences will lead students to discover and expand their intuitive and their rational capabilities.

In the end, it seems clear that the importance of the potential gains in technology and engineering education makes the effort not only worth pursuing but necessary for excellence.
REFLECTIVE QUESTIONS

1. The authors of this chapter suggest that design is a process that draws on both the left side and the right side of the brain. What are some practical ideas you might use to push your students to use creativity in the design process?

2. Barry Yatt is a practicing architect and design educator. In what ways does the discussion in this chapter challenge the leaders of and teachers in technology education as the profession moves toward engineering?

3. How could you restructure projects you currently use in class so as to ask students to stoke and to brainstorm – to stoke their subconscious in preparation for brainstorming, and then to brainstorm some preliminary solution ideas?

4. Do you agree with the authors that story is a critical element in the design process? Why or why not?

5. What opportunities or problems do you think the challenge/responding approach proposed in this chapter might have for you or your students?

FOOTNOTES

1 Additional information on Museé des Campagnonages in Tours, France can be accessed at http://www.compagnons.org

2 Creative Thinking Skills for Life and Education by Craig Rusbult http://www.asa3.org/ASA/education/think/creative.htm

3 Creativity and Creative Thinking (includes lesson plans) by Mary Bellis: http://inventors.about.com/od/lessonplans/a/creativity.htm

4 Ken Robinson says schools kill creativity http://www.ted.com/talks/lang/eng/ken_robinson_says_schools_kill_creativity.html

5 Architecture+Design Education Network and Association of Architecture Organizations http://www.adenweb.org/
REFERENCES


Defining Creativity and Design


