Session 2661

Synthesizing Creative Processing in Engineering Curricula through Art

Angela H. Patton, Richard B. Bannerot

University of Houston

Introduction

Engineering stands poised between mind and matter. It is a discipline that gives shape to unseen forces and application to scientific query. Translating ideas and phenomena into accessible forms requires ingenuity. Engineers imagine and invent. In the context of engineering education, creativity is recognized as a valuable attribute. And yet, most engineering programs lack an effective means of synthesizing creative processing into the core values of the curriculum.

In 1828, the Institution of Civil Engineers defined engineering as "the art of directing great sources of power in nature for the use and convenience of man."[1] By 1956, this definition expanded beyond harnessing physical phenomena to include "application of knowledge" and "design and production."[2] What remained consistent however, was the idea that engineering is artfully disposed. This suggests a level of care and understanding that conjoins thought and feeling. If the transformation of science and technology into products and systems requires empathy or "emotional union,"[3] (i.e., the projection of self into objects) then the education and training of engineers should include an understanding of intuitive processing.

Engineers must have proficiency in the basic languages of math and science in order to affect the physical world. Engineers must understand phenomena on an elemental level as they seek to pilot the laws of nature. Consider that -- the laws of nature are based on universal principles of order, organization, and efficiency – all basic tenets of design.

Design mediates between tangible and intangible forces. It fuses the immediacy of the physical world with the illusiveness of beauty. Design is driven by a museful urge to create; and, it is tempered by the physical limitations of the material world. In this paper, we explore design theory and design process in the context of art as a means to structure creative processing into engineering curricula. Our perspective is based on an existing undergraduate, interdisciplinary teaching initiative forged between engineering and art where visual principles of design are introduced and exercised. Acclimating students to the language and culture of design serves to demystify the creative process and enhance imaginative problem solving. Because design prizes intuitive processing and offers an effective method for cultivating integrated thinking skills, it is a valuable course of study for engineering students.

Invention vs. creation

Within the cultures of engineering and art, we find that engineers are more likely to invent while artists are thought to create. In some respects, these terms are interchangeable. But, on a subtle level the semantic differences are revealing. Invention is a creative act, but carries with it connotations that suggest purpose and utility rather than emotion and pure aesthetic. To create encompasses invention, but creation is more often associated with expressiveness. Invention is grounded in objectivity; creativity is tangled in subjectivity. Engineers think, artists feel; engineers calculate, artists compose. Entire disciplines have evolved around the distinction between reason and intuition serving to isolate one from the other.

There was a time, however, when the boundary between art and engineering was not as palpable as it is today. Consider the work of the artist and engineer, Leonardo da Vinci. As the quintessential Renaissance figure, his genius knew no bounds. His insatiable curiosity and keen mind contributed significantly to the evolution of knowledge. It was as if the forces of nature conspired to bring da Vinci into being for the sole purpose of exposing the inner workings of the world. Da Vinci did, after all, peel back the outer layer of the visible world, summoning human query and inspection.

Centuries later da Vinci's name is synonymous with creativity and ingenuity. This has inspired savvy minds to condense his genius into a seven –step program[4] designed for global distribution. These efforts strive to classify, regiment, and make concrete an illusive, visual, and highly intuitive process. This is not to say that da Vinci's style of thinking is inaccessible. It is to say that as an innovator and originator, da Vinci's genius seems ill-suited for contrived homogenization. And yet, packaging creativity in a "user friendly" format is a typical response of linear thinkers who favor a direct path (i.e., step one, two, three) rather than a circuitous and adventurous route.

To think like da Vinci, we must place ourselves in similar circumstances and equip ourselves with similar tools. In other words, we must experience directly and not rely on prescriptive methods or contrived directives. Like da Vinci, we must be confronted with making known the unknown, making visible the invisible, making something from nothing. Da Vinci's tools were his integrated heart and mind. This coordination cultured a more comprehensive method of thinking that enabled da Vinci to glide effortlessly between beauty and utility, allowing him to comprehend on a much deeper level.

Beauty

In building a case for intuitive processing, the culture of art may elude a rational mind. However, the art-related fields of design and architecture are more accessible and easier for engineers to assimilate. While engineering and architecture may "march together and follow one from the other,"[5] they are viewed differently. One is more prosaic; the other one is more sublime. Through ingenuity, “stone, wood, and concrete”[6] find practical application in construction. But, beyond the realms of ingenuity and practicality there are regions of human awareness that are left wanting for more. According to the twentieth century architect, Le Corbusier, architecture, more than shelter, more than construction, can “rise to heaven in a way that (we) are moved.”[7]

While Corbusier advocated an aesthetic, “organized without ambiguity,”[8] he was also a proselytizer of artfulness. On the surface, his philosophy appears contradictory because it is both reasoned and emotive. Consider that in the most extreme sense, the disciplines of engineering and art evolved from the premise that mind and emotion, utility and beauty, function and form are incompatible. And yet, Corbusier could not find one without the other.

Corbusier cites beauty as the agent that aligns us “in perfect accord with nature.”[9] He defines harmony as “a moment of accord with the axis which lies in man – a return to universal law.”[10] This sentiment is echoed by the mathematician, Henri Poincaré who contends that the “harmony expressed by mathematical law” is the “sole objective reality.” He adds, “The universal harmony of the world is the source of all beauty.”[11] Beauty is found equally in the elegance of a mathematical construct as well as the subtle contour of a wandering line. This aesthetic disparity is possible because true reality exists beyond the surface value of the visible world where numbers and marks are indistinguishable.

Where there is beauty there is harmony; where there is harmony there is balance. Harmony is the benchmark of reality. It is human consciousness that enables the objective and subjective to converge. If left alone, these two modes of thinking offer incomplete accounts of reality. There is a reason that we can think and feel, rationalize and intuit, compute and compose. To synthesize our world, we must utilize both of these faculties.

Before scientific validation, the work of artists and poets gave merit to the harmonic disposition of the universe, not through formulae, not by theory, not in fact, but through instinct and intuition. It should be noted that intuitive sojourns are not exclusive to art and design. In Kepler’s, *Harmony of the World* he muses, “All pure Ideas, or archetypal patterns of harmony are inherently present in those who are capable of apprehending them. They are not first received into the mind by a conceptual process, being the product, rather, of a sort of instinctive intuition.”[12]

Engineering traditionally does not put stock in the “softer side” of awareness despite the fact that “Studies at Harvard Business School have found that managers and presidents of national and multi-national organizations attributed 80 per cent of their success to acting on intuition or ‘“gut feeling.”’[13] Engineers are cultured to reason. The world is right or left, on or off, black or white, true or false leaving little room for interaction between these extremes.

Intellect vs. intuition

Consider that the intellect sorts and classifies, locates and measures, distinguishes and determines. In an effort to understand the physical world "we have reduced and described and separated things into cause and effect, and drawn the world in lines and boxes."[14] Consequently, our perception of the world is based on a mechanical, object-oriented reality defined by edges and boundaries, biases and barriers. Reality becomes a cultured point of view based on a perception of parts and pieces.

In contrast, intuition is more fluid. It is more primal in nature, harboring our instincts. Intuition has the capacity to shepherd the intellect past its tendency to separate and isolate. Where the intellect divides, intuition merges. As the philosopher Alan Watts describes, there are "instruments of the mind, which are vague, misty, and melting rather than clear-cut. They provide possibilities of communication, of actual contact and relationships with nature more intimate than anything to be found by preserving at all costs the distance of objectivity."[15]

While the efforts of engineers affect the physical world, conventional engineering curricula rely more on mental processes than on physical ones. We tend to regard mental work as a superior effort. While this position has merit, it has a consequence of isolating mind from matter, segregating thought from feeling. Consider the educational strategy of a highly celebrated German design school that based its curricula on the cultivation of a more holistic method of thinking and, in doing so, revolutionized twentieth century aesthetics.

The Bauhaus

The Bauhaus was established in 1919 to develop and promote modernist ideals through design and architecture. The Bauhaus remains one of the single most influential forces in design education. The Bauhaus was a conscious effort to dismantle the decadence of nineteenth century values and establish a New World order by affecting the built environment. It is significant to note that the school's first proclamation declared, "Architects, painters, sculptures, must all return to the crafts."[16] In many respects, a pedagogical approach based on a seemingly archaic style of working appears inconsistent with the forward motion and technical adeptness of modernism. And yet, cultivating a hands-on curricula and journeyman method of study was at the pinnacle of the Bauhaus methodology.

The foundation design course at the Bauhaus, as taught by Johannes Itten, was not confined to visual discourse. Itten advocated, "The introductory course concerns the whole student's personality, since it seeks to liberate him, to make him stand on his own feet, and makes it possible for him to gain knowledge of both material and form through direct experience."[17] Interacting directly with materials establishes a level of understanding and knowing that cannot be discerned from the distance of the intellect

The method was two fold: 1) establish "Handicraft as a teaching discipline. In other words, "learn by doing rather than learn by reading or listening to lectures;"[18] and 2) cleanse “every incoming student’s mind of all preconceptions” in order to “liberate the student’s creative power.”[19] Although based on a more primitive method of working (i.e., craftsmanship), the products that emerged from the Bauhaus marked a radical departure from the status quo. Forms were authentic and original and are still valued (and marketed) today. The Bauhaus did advocate principles of mass production and standardization, but its teaching methodology was grounded in a process that was personal and hands-on.

Under political pressure, the Bauhaus officially closed its doors in 1933. Over the next few years, many of its esteemed faculty migrated to the United States bringing with them the Bauhaus method. Here, they settled in art and architecture programs at prestigious universities (e.g., Harvard, Yale, Illinois Institute of Technology). The New Bauhaus was founded in Chicago in 1937 as the School of Design and in 1944 was renamed the Institute of Design. The program later merged with the Illinois Institute of Technology where it still exists today.

The studio format, as endorsed by the Bauhaus, is now common to art and design programs. This educational approach is structured to give a direct experience. According to the architect Tom Bender, “The only significant learning is self-discovered and self appropriated. Such learning cannot be directly communicated to another.”[20] This method encourages integrated thinking skills, as students are required to balance visual awareness with reasoned assertions. Consider that students must translate visually projects they receive in written and verbal forms. This transformation has a consequence of exercising their full cognitive abilities. Working visually is a complex process that includes spatial considerations and manual dexterity (e.g., hands must be skilled and steady). Students not only reason and intuit; but they also touch, build, and manipulate the physical world.

The essential value of introducing a studio format to engineers is that by “acting on the external world and changing it, he (man) at the same time changes his own nature.”[21] The desired change in this case is to cultivate dimensional thinking by fostering a more balanced approach to problem solving. From the perspective of our interdisciplinary teaching venture, this enhanced ability is facilitated by an exposure to visual awareness through basic design principles.

Design principles

In some respects, identifying principles of design is a risky business. Because of the linear and highly sequenced processes that engineers follow, they are predisposed to look for rules or formulae. It is a natural tendency of the mind to convert patterns into doctrine. But a penchant for setting boundaries and imposing limitations, while comforting to the intellect, is oppressive to the soul. This is not to suggest that there should be no parameters. On the contrary, design is driven by givens or existing conditions and requirements (e.g., size, material, time frame, budget) in conjunction with goals and objectives. However, well-defined parameters only address the practical aspects of design. The full scope of design places parameters within an aesthetic context.

Design principles are not about doctrine or dogma. They are more philosophical than functional, more global than local, representing the foundation of visual expression. These ideals are not an end but a means. Design tenets are not associated with style or fashion but are expressions of basic human values. For instance, when designing we seek **balance** because a balanced state is the most optimal condition of awareness. We strive for **wholeness** because it is the most complete sense of reality. We beckon **beauty** because it resonates within us, shaking the inertia of the human corpus, and provoking a dynamic response to the world. As Plato describes, “The soul is awestricken and shudders at the sight of the beautiful.”[22]

To complicate matters more, these seemingly illusive and museful qualities of design must exist in the context of practicality. In design, form has **function** and **purpose**. If something looks good, but does not operate well it is not considered good design. It is tempting to isolate how something looks from how it works, but in design these are inseparable features.

Efficiency, while more rationally disposed, is also considered a basic condition of design, representing self-control and restraint. Alone, efficiency does not always reap the best results. In conjunction with the other cited principles, however, **economy** introduces a level of composure that strengthens and grounds the visual and functional considerations.

Because design is contingent on many factors, **appropriateness** is a defining feature. This consideration translates into **user awareness**. In other words, designers make decisions based on what is most appropriate for the given situation. Identifying the user and user need is primary when designing. Design must factor into its repertoire user dynamics. Design disassociated from the user is not good design.

When affecting the built environment, it is essential that we process thoughts, feelings, and ideas in a way that emulates the **dimensionality** of nature. The physical world has depth and dimension; it is spatial and volumetric. It is, therefore, impossible to discern fully the world from a single point of view.

Designer, Charles Eames “liked to quote Eliel Saarinen on the importance of always looking for the next larger thing – and the next smaller thing.”[23] In other words, once we have made a determination, drawn a conclusion, isolated an idea, or settled on a direction we should take the time to look one step beyond and one step removed. This is how ideas are calibrated.

Design process

More valuable than a set of visual principles is an understanding of the design process. In essence, design is a method of thinking that spans the distance between idea germinating and idea realizing. Its use of a visual language and intuitive processing serves to compliment the conventional practices of engineering. Exposure to processing enables students to maneuver their way through unfamiliar circumstances.

The journey begins by declaring design objectives and defining the givens and requirements. Setting goals and identifying known values give shape and direction to a solution. How intention and attributes are realized fall into the “unknown” category. This is where visualization occurs. At this point, linear processing has little value (e.g., step one, step two). What structures the transformation of thoughts and ideas into form is a method of working that begins broadly and gingerly as we inspire ideas to make an appearance. In some circles, the terms “brainstorming or mapping” are used to suggest a dynamic state of awareness that searches out all possibilities. In design, we typically sketch loosely and vigorously as we research the value of an idea. Sketches usually include written notes, indicating a process that draws from all sectors of the brain. Designers, simultaneously, juggle objectives, givens and requirements, and design principles, indicating mental dexterity. This is the gray zone. This is where our intuitive faculties are most active. Sometimes ideas come easily; sometimes they are obstinate. Processing teaches us the art of protracting ideas, when to walk away, when to stay. It is the dynamic play between our intellect and intuition. We think and feel our way to solutions. Once satisfied with the visual direction, designers work to develop further and refine the final form, making it more precise and concrete. The charm of design is solely in the process.

Included in the design process is the idea of input and feedback. The critique method enables students to gain perspective. Sometimes we make false assumptions about our own work. Sometimes things that seem clear to us are not obvious to others. One aspect of a critique is that it functions as a checkpoint, letting us know how visually effective and persuasive we have been. Critiques also cultivate collaboration by facilitating an exchange of ideas. By exposing students to constructive criticism in a group setting, they acquire a more objective attitude towards their work. In other words, they learn not to take criticism personally, but rather view it as an opportunity to strengthen their ideas and outcomes.

Practical considerations

While visually oriented design projects are outside the bounds of an engineering student’s perceived expertise, they are oddly within the realm of his or her biases. Students initially express skepticism about these exercises and question the relevance of them to engineering. Their assumptions are based on preconceived ideas and a hierarchical framework that places aesthetics and design in a lesser position than practicality and engineering. Ironically, the superficial qualities that engineering students associate with design and use as evidence of its insignificance are the very qualities that they gravitate towards and exercise when given visual assignments (e.g., style, color, pattern). Those not fluent in the language of design are inclined to focus on superficial aspects (i.e., appearances), because they do not have access to the underlying process that synthesizes form and function. Surface considerations are outcomes, representing conclusions, not beginnings. Because the students’ understanding of design principles is limited their ability to discern visually is impaired. They may feel that all that is at stake is an ability to make something “pretty,” but in fact; their observation skills are compromised.

We address the issue of making assumptions by using examples such as this antic dote from the author, Michael Crichton. Crichton tells the story of living in a service-oriented hotel for an extended period of time while rewriting a screenplay. This was before the age of the personal computer with a cut and paste feature. Crichton, therefore, accomplished the same effect with scissors and tape. Lacking a tape dispenser, he stuck strips of tape on the desk in his room as he worked to organize and develop his story. On a later trip, he returned to this same hotel. In an effort to make his stay comfortable and personalized, before he arrived, the staff put tape on his desk not realizing that the adhesive had had a distinct purpose.[24] To those servicing his room, the assumption was made that Crichton had an affinity for tape stuck to furniture. The point being that, with the best of intention, a judgment was made based on superficial observation and incomplete information. To see is not always to know. This is a valuable lesson on many fronts. For our purposes, Crichton's experience illustrates the folly of assuming that visual and aesthetic considerations are irrelevant to the functionality of engineering.

We find it helpful to demonstrate that art and engineering are both aesthetically inclined. On a fundamental level, art and engineering both strive for elegance, beauty, and efficiency. There are many examples of scientists and mathematicians such as Henri Poincaré and Bertrand Russell who discuss beauty in the language of science.

We attempt to guide thinking away from stereotypes and towards a more informed point of view. To this end, we preface the hands-on projects with a general lecture and slide presentation on design. The objective is to dispel predetermined ideas and chip away at biases that impede discovery. This parallels Itten's approach at the Bauhaus. He saw the need to cleanse students' preconceptions in order to release their creative power.

Once students are given an assignment they are guided to ask questions. In the beginning the questions are of a practical nature as students strive to define "exactly" what they are to do. They quickly learn that there are appropriate and inappropriate questions at this stage of the project. For instance, those students who are motivated to know the equivalent of "how many pages, paragraphs, and words" solutions need to be are clearly not interested in mental meandering and discovery. They are motivated to "get the job done," finding an answer as fast as possible. While some may argue that this represents an efficient mind, in the context of design, it reveals someone who does not respond well to the discomfort of not knowing and has no interest in thinking for him or herself. At this stage, we turn the questions back on the students. Here we review project constraints, we ask questions to help the students better identify what they do know as opposed to what they don't know. They have to deconstruct the unknown before they can maneuver in it.

For instance, in a simple exercise on composition they may know the size of the field (e.g., five inch square), they may know the material (e.g., museum board), they may know that they are affecting this field with different shapes (e.g., circle, triangle, square, line), they may know that they need to address both positive and negative space, but where these shapes are located within the five inch square and what is solid and what is void represent unknowns. We walk them through how to make these determinations. In other words, what is guiding their decisions? In an exercise such as this, there is no "rational" way to proceed; students must rely on their aesthetic judgment. At this juncture the engineering students feel most awkward and ill-prepared. This is where the art students are most valuable to the engineers as they "model" the way.

What the students discover is that there are visual consequences to their decisions. For instance, a composition may have a sense of balance and harmony, or it may have a sense of confusion and fragmentation. Because the solutions are visual, these qualities are very obvious. We address why this is the case, focusing not on the outcome, but focusing on students' styles of thinking. The reality is that the models that they build parallel their thought process. If the outcome is disjointed and lacks basic order and organization then it is an indication that thinking is chaotic and muddled. Using the models as a point of reference, we can help students identify where their "thinking" is on target or off course.

Another consideration to working visually is that it reveals natural tendencies. In other words, are students more inclined towards details or "big pictures?" This realization is very valuable when developing thinking skills. Once an assessment like this is made, a student can be directed to pull back or push further. Once students see for themselves that they have a propensity for one way of thinking or another way, they can consciously work to adjust their approach so that they end up with more balanced outcomes.

In general, design counsels students to work from large to small; details should be organic to the process. In other words, the large-scale decisions give shape, form, and guidance to the determinations at a smaller scale. It is possible to work in the opposite direction, (i.e., small to large), but this approach requires more visualization skills and more developed instincts.

Students are exposed to design principles and design processing through three-dimensional exercises. These hands-on projects provide an opportunity to apply and assimilate the language of design, bringing form to function. More importantly, because these exercises lie outside of an engineer's normal scope of inquiry they represent unfamiliar circumstances. In problem solving, learning how to manage and work through unknowns is essential.

Engineering students are accustomed to being challenged; but they are challenged in a way that is familiar to them (e.g., math, physics). Visual exercises create an opportunity to "simulate" the unknown in a way that cultures an ability to deal with awkward and uncomfortable situations. Consider that the nature of problem solving is tackling obstacles and being confronted with unresolved circumstances. Fear is restrictive and not conducive to innovation. Learning to be comfortable with the unknown is a prerequisite of spirited discovery.

While often frustrating and disquieting, discovery is a necessary phase in problem solving and requires the full faculties of human awareness. To effectively realize a solution requires that we participate in the germination of ideas. We must be willing to trudge through the mud and endure the discomfort of disorder as we provoke and prod, coax and congeal unformed (and sometimes uncooperative) vagueness into accessible ideas. Without this level of interaction we are disassociated from the process. Rather than give life to ideas, we serve a surrogate role. This is a critical point to make when introducing design culture to students who are more accustomed to linear processing and more at ease with controlled circumstances.

Conclusion

As an agent of the physical world, engineering gives direction and purpose to unseen forces. Because of this, engineering plays a defining role in the mechanics and appearance of daily life. Design is also an agent of the physical world. Design, like engineering, honors its obligation to practicality, and efficiency. But beyond satisfying principles of economy, design feeds its soul with beauty. Aesthetic judgments are rendered intuitively. Intuitive sojourns are not foreign to engineers; mathematical equations have the power to stir and move us. Despite this, intuitive reasoning is not recognized as a viable component in problem solving. Conventional practices in engineering serve to isolate thought from feeling. This condition serves to fragment awareness and undermine the ability to shape solutions.

Despite the wealth of diversity that the world displays, modern science has revealed that at more refined levels of existence the universe is indistinguishable and continuous, displaying a "unity of conduct."[25] How do we fathom objective reality when the material realm and all its complex multiplicity appear to be incongruent with the unified wholeness that underlies creation? How do we reconcile that what we see is not a complete account of reality? And, how do we design, build, and invent for such a world?

Design is useful because it sits at the juncture between utility and beauty; and, therefore it speaks a language that is both comprehensible and challenging to engineers. Design theory and design process give framework to and make accessible the intuitive realm, thus enhancing an engineer's capacity to formulate ideas. On a practical level design, as a visual exercise, enables students to physically manifest their thoughts. In this way, ideas leave the coffers of the mind where they exist in a formless state. Once thoughts are expressed in real time, they can be touched, admired, or admonished. In this way, students can reflect on outcomes, turning forms back and forth, over and under, in and out. This process of realization and reflection strengthens a student's ability to think dimensionally.

Although design is regarded as a field of study in its own right, it is both the impetus for and the outcome of an orderly universe. In essence, design is about relationships -- how things come together, touch, and overlap. It is how the world locates, positions, and aligns itself. Design is a ubiquitous force mediating between parts and pieces, bringing order and organization to the infinite variance and complexity of the visible world. In this sense, understanding design on a rudimentary level is essential to any program aimed at shaping the visible world. Without supplementing engineering curricula to include knowledge of visual considerations, engineering students are disadvantaged. Function dominates form to such an extent that the functional value is compromised.

The scope of engineering's inquiry has increased dramatically with advancements in science and technology. Ironically, engineering curricula grow more detached and specialized as the material world grows more networked and complex. Except for general core courses and instruction in math and science, engineering programs tend to be self-absorbed. This myopic condition is inconsistent with the values of a global economy. The interdisciplinary aspect of this collaborative venture serves to broaden the scope of engineering curricula in obvious and subtle ways. Most noticeable is the value of introducing a different point of view that serves to provoke new discoveries and connections.

Studies of creative individuals, such as artists and designers, reveal characteristics of playfulness, risk-taking, passion, curiosity, open-mindedness, and visual acuity. In contrast, engineers are reputed to be more serious, conservative, reserved, precise, measured, and mentally inclined. Taken at face value these disparate and albeit stereotypical characteristics suggest that the engineering psyche is not programmed for creative work. While we do not subscribe to this point of view, we do recognize that, in engineering, conventional teaching methodologies serve to condition the more analytical side of the brain at the expense of developing intuitive faculties. Rather than accept the disparity of engineering and art as being irreconcilable, we find that in combination these disciplines afford educational opportunities that result in synthesizing creative processing and culturing integrated thinking skills. Rather than convert engineers to artists, we strive to culture artful engineers.

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Biography

ANGELA PATTON

Angela Patton is an associate professor of Art at the University of Houston. Her expertise is foundation design and design theory. Her visual work includes award winning environmental projects, products, images, electronic media, and works on paper. Her written work synthesizes design theory with other disciplines. Her most recent writing considers design in the context of digital awareness.

RICHARD BANNEROT

Richard Bannerot is a professor of Mechanical Engineering at the University of Houston. His research interests are in the thermal science related areas, especially heat transfer and thermal system design. For the past ten year he has taught the required "Introduction to Design" course at the sophomore level to mechanical engineering students.