Ambidextrous Thinking

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Abstract
ME 313, Ambidextrous Thinking, was created in 1988 to meet the needs of incoming Masters degree students in the programs of Mechanical Design, Manufacturing Systems Engineering and Product Design. It serves as an introduction to the unique spirit and tradition of the Design Division of Stanford's Mechanical Engineering Department. It also serves as a test bed for the evolving design philosophy of the instructor who has spent over twenty years thinking about how to best foster creativity in the university setting.

Encouraging experimentation and creativity utilizing engineering design projects is hopefully widespread. What is more likely to be considered unusual about this class is the efforts it makes to acquaint engineering graduate students with the full range of human potential in order to encourage a "whole person" approach to problem solving.

This paper describes the background and underlying philosophy of the course, how it is structured, and, because it is pertinent, a description of how it is taught. Those areas which are perceived to be distinctive will be given more attention. These include the importance of freehand visualization, kinesthetic involvement, a teaching pedagogy which minimizes instruction in favor of action, and the lengths taken to encourage energetic involvement without using competition or grades as motivation.

The Meaning and Mission of Ambidextrous Thinking
Combining "Ambidextrous" with "Thinking" creates at least two intended images. "Ambidextrous" means the ability to use both hands, so the first image implies the use of the hands, and by extension, use of the whole body, in creative thinking. From Archimedes to Einstein there are so many examples of the importance of kinesthetic thinking that it is a shame not to recognize this fact and encourage its use in engineering.

A second image suggests extending the notion of ambidexterity to the brain, that is, being equally facile with both the right and left sides of our brain. Table 1 lists the attributes associated with right and left brain functioning. The terms Right Mode and Left Mode are used to avoid entanglement in the rapidly evolving theories of brain function. A brief look at this list will confirm that schools and universities in our culture, and particularly engineering programs, uniformly emphasize left mode, or verbal, quantitative, and logical symbol manipulating skills at the expense of right mode skills.

Table 1. Attributes of the Left and Right Modes

LEFT MODE	RIGHT MODE
Symbolic	Visual and Kinesthetic
Logical	Intuitive
Segmented	Holistic
Sequential	Non-sequential
Detached	Involved
Objective	Emotional
Linear thinking	Pattern Recognition
One-at-a-time	All-at-once, Coordinated
Sequential	Simultaneous
Vertical	Lateral
Specialist	Generalist
Deductive	Inductive
Analytical	Relational
Quantitative	Qualitative
Discrete, Separate	Integrated, Whole
Neat and tidy	Messy
Digital	Analog
Verbal	Non-verbal
Anaesthetic	Aesthetic, Involved with senses
absence of	Visual, Haptic,
real-time	Kinesthetic,
information	Olfactory, etc.
Reduction	Synthesis
Categorizing	Wholeness, Seeing similarities
Conscious of time	In-the-moment, No time sense
Black and white	Full color spectrum
Focused thought	Meditative
Thing oriented	Relationship oriented
Masculine traits	Feminine traits
Understanding	Knowing
"Thinking"	"Being"

Piaget described three stages of human development: a body-centered stage, a visual stage and, beginning at age eleven or twelve, a symbolic stage. When problem solving becomes blocked at the symbolic level, humans must revert to the right brained abilities associated with these previous stages. The symbolic level involves the use of conventions, societal agreements about what words and symbols signify. Breakthroughs often require questioning these conventions. For this one must examine the original sensory data. In other words, humans can and do think with their entire brain and with their eyes, hands, and whole body. Problems become internalized, and worked on by the entire body, not just by conscious thought. In a very real way, original thinking requires going back to one's origins.

ME313 grows out of a course called Visual Thinking which has been required of all undergraduate Mechanical Engineering students for over thirty years. "Ambidextrous Thinking" was chosen as the name because it alludes to more than visual thinking, and also to solving problems using all of an individual's talents and resources. At the graduate level, this second attribute is a definite plus—it values incoming students' analytical skills while introducing new ones. Brain-body functioning should not be and issue of either/or but rather both/and.

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In summary, Ambidextrous Thinking encourages a flexible and interdisciplinary way of working which abandons inappropriate mental barriers and stereotypes. The result is the ability to combine and experiment with ideas in a fluent and flexible way that consistently generates successful designs.

Course Goals and Structure

Ambidextrous Thinking strives to achieve four goals: 1., to give students a first-hand experience of the role visual, kinesthetic and inner imagery play in productive thinking; 2., to help students understand the relationship between perception and creative problem solving, and to develop the interrelated skills of seeing and rapid freehand drawing; 3., to improve students' fluency and flexibility in the generation of ideas and design concepts; and 4., to give students a better awareness of their cognitive style, and to better appreciate the thinking skills of others.

To achieve these goals, the ten-week quarter is divided into four parts, all but the first marked by the completion of a design project. Throughout, a process with the acronym ETC, or Express, Test, Cycle, is encouraged. In this process the students alternate between a non-judgmental idea generating mode and a judgmental focusing mode in an iterative way using a variety of creative strategies that range from verbal brainstorming to rapid prototyping.

The first two-and-a-half weeks are devoted to seeing and freehand sketching. Exercises are given which demonstrate that anyone can learn to draw, and to draw well. Life drawing is done at the beginning and perspective sketching from the imagination is introduced shortly thereafter. All these visual skills developed by freehand drawing are becoming increasingly crucial as engineers move in to stronger CAD environments.

Rapid freehand drawing is more than a useful tool for designers, it provides an instructive metaphor both about the design process and about being creative. Drawing well requires a willingness to get into the non-judgmental right mode. At the same time, drawing accuracy can be enhanced by applying critical left mode skills involving proportions, angles, grids, and logically constructed underlays. In other words, the drawing process itself can oscillate between left and right modes in a way similar to the design process itself.

Curiously, people in our culture often associate the ability to draw with being creative. Many students find themselves in the pleasant situation of having learned to do something they were convinced they never could do. This often makes them question other behaviors which they assumed they had no talent for or otherwise assumed were unavailable to them. This is an empowering insight which can release a range of creative response.

After this exposure to drawing comes a two-week project involving teams of five students. This culminates in an event for which each member of the team must have constructed hardware out of a limited set of materials such as foam-core, string, rubber bands, white glue, etc. These team projects are often based on current events. For example, the last three years' projects have been: providing relief aid to Somalia ('93), predicting the presidential election ('92), and diffusing nuclear arsenals after the break-up of the Soviet Union ('91). It is my belief that projects intended to encourage creativity should never be repeated. A new project avoids the tendency, however unintentional, to create pressure towards a "correct answer" (the best previous solution). More importantly, the instructor must take risks if he or she is to set an example which encourages students to take risks. Ideal projects sound impossible at the beginning, yet result in a success rate of 75% or more.

The next project is about three weeks long and is the principal focus of the course. It is typically done in teams of two, and involves the creation of a mechanical device that achieves a functional goal. Examples include creating a pair of devices that play hacky-sack or tennis, that dance, or even simulate alien robots greeting each other and exchanging business cards. This past year's assignment involved to "acrobots" on three parallel high bars cantilevered two feet apart. The acrobot on the center bar had to help the acrobot on the first bar so that they both arrived at the third bar together. This was a particularly satisfactory project in that it yielded an unusually large number of successful solution strategies (see Fig. 1, Mind-Map of Solution Types for Acrobot Project).

As the quarter progresses, course emphasis shifts from drawing to idea generation strategies. Creative techniques are introduced in the context of the assigned problems. In addition to common tools such as brainstorming, Synectics and morphological analysis, new tools are constantly being tried and tested. These include improvisational drama, visualization techniques borrowed from athletics, mind-mapping, how/why diagrams and story-boarding. Again the notion of taking pedagogical risks plays a role. Guest speakers have introduced subjects such as Lucid Dreaming, theta-wave bio-feedback, yoga, the role of posture, focusing by means of micro-movement and humming, etc. Last year an instructor from the Athletic Department had the class visualize possible problem solutions using jazz dance. This fall, "Brain Gym" exercises developed by the Educational Kineseology Foundation will be introduced.

The third and final project involves an introduction to need-finding and product definition. Each student explores a need revealed by recording personal irritations on an extensive "bug-list". In essence this project is a two week take-home exam which challenges the students to use all the skills and techniques introduced in the course.

In addition to homework and projects, readings are provided that illuminate the psychological research and extensive philosophy that underpin the course. Numerous examples of Ambidextrous Thinking from the history of science and technology are included as well.

There are twenty-one two-hour classes in Stanford's ten-week quarter. Each class is divided into numerous segments consisting of warm-ups, mini-lectures, hands-on activities, critiques, and exercises. The Professor and two Teaching Assistants trade off running the class much like a tag team in a wrestling match. Lectures are rarely more than ten to fifteen minute introductions of theory and are immediately applied in activity. Many activities involve working along with the instructor. Others involve working alone or in teams. There are frequent guest speakers and visiting faculty from other departments. The classroom is equipped with sixty mobile 2' by 4' tables which allow rearrangement to suit the needs of each activity.

Pedagogical Approach

Several comments have already been made about the manner in which the course is taught. One concerned the instructor setting an example in risk-taking. This philosophy is based on McLuhan's saying, "The medium is the message." While there is a lot that can be said about this subject, this particular class is essentially about process. Thus, words are less important than doing, and the way in which something is done is as important as what is done.

A related issue is that understanding is less important than getting it. "Getting it" in design can be compared with telling a joke. If people are told a joke and they don't understand it, they will ask to have it explained. After the explanation they will understand it, but they won't laugh. There is nothing funny about the explanation nor the understanding that accompanies it. The point of telling a joke is "getting it"—that is, experiencing the sudden juxtaposition of contradictory concepts and releasing the built-up tension with laughter. It is our intention that students "get it" regarding their ability to draw and to generate creative solutions to problems. For further insight on this issue I highly recommend **Zen in the Art of Archery** by Eugen Herrigel.

To accomplish this we use a teaching strategy we call "bounce-hit." In **The Inner Game of Tennis** Tim Gallwey describes a method for keeping left-side consciousness occupied with a task while letting the right side get on with it. He asks beginning tennis students to say "bounce" when the ball bounces and "hit" when the ball is hit. He says nothing about how to stand, hold the racket or swing. Instead, the students consciousness is focused on a nice easy task while the body gets on with playing tennis. His approach makes it difficult to be thinking critical thoughts like "I swung to late" or, perhaps more importantly, "I screwed up." We try to incorporate this idea in all our teaching. For example, I no longer lecture on perspective, we simply get on with it. Using this method, drawing correct circles in perspective can be taught in about a half an hour. An observer will hear the students saying a little mantra, "axle, ninety degrees, major axis, ellipse."

Another strongly held belief concerns competition. None of the assigned projects requires or encourages students to compete with each other. Quite the reverse; students and student teams are asked to pin up all their ideas on the wall every class and share them with the whole world. In the spirit of T.S. Eliot's dictum, "Good poets copy, great poets steal," students are encouraged to incorporate and improve on any idea on the wall, whether it is theirs or not. At first, students rebel at the thought of sharing their great initial ideas with others. With reluctance they begin to see that what they thought was a great idea was also thought of by three other groups, or that other groups had better ideas, or that their idea combined with another's would make a really good idea. At presentation time it becomes clear that the whole class "wins" when each team shows an outstanding solution.

A related aspect of these projects is worth mentioning. The presence of an audience, i.e., the class and visitors, is always included in the instructions. In this way, both aesthetic and utilitarian success are strived for. Team attitude and spirit reveal themselves by the presence of strong team themes accompanied by costumes, props and appropriate soundtracks. Invariably, the projects most successful at achieving the physical goal of the project are the ones which also please the onlookers.

The teaching style described above doesn't appeal to everyone. Many students would rather feel safe than challenged and exposed. It helps these students to discuss course intentions, pedagogical strategies and resulting feelings as the quarter moves along.

Grading

Grading a course intended to encourage creativity has several significant drawbacks. For the student, grading encourages conservative behavior which stifles spontaneity and risk–taking. When students look to teachers for evaluation and approval, they have difficulty learning to trust their own intuition and motivation. They also often fail to develop skill and confidence in the important art of judging their own work.

After a few years of teaching the course with grades it became clear that they were interfering with achieving course goals. I found myself trying not to influence students by revealing opinions regarding the quality of their designs, and these judgments, expressed or not, were getting in the way of expressing enthusiastic encouragement. So the course was changed to a pass/no credit grading system.

The very real risk in not grading is having the students pay more attention to competing classes. Fortunately, excitement and peer pressure have proved to be sufficient to counteract this tendency. It is instructive to mention an event when it wasn't sufficient. Several years ago the second design project only had about a 30% success rate. The assignment was to create a device that would transport itself entirely from one table, over a bar onto another table. It was easy to go over a bar. It was hard to land on the opposite table. Given other pressures, most students opted for jumping or shooting devices hoping that luck would work in their favor. As I watched the edited videotape reveal near miss after near miss in rapid succession I realized that my intentions for the class were being sorely tested. Creative techniques may be fun, but they only make sense when coupled with the serious intention of solving the task at hand. Much to the students' chagrin, I reassigned the problem.

This experience only reinforced my non-grading policy. I am freer to do my job as a teacher when I can forcefully present my point of view when I know the student won't be penalized if he/she disagrees.

Since deciding to drop letter grades there have been some delightful surprises. Freed from concern about being graded, one student filled her entire personal log with drawings done with their non-dominant hand (left in this case). Another took this opportunity to do something he always wanted to do: write poetry. Every day after class he wrote a poem based on his feelings about his experiences.

Student response to this policy has been overwhelmingly favorable. A few of the class exercises and some of the readings strike them as coming from outer space. Individuals will love or hate such apparitions, some will feel both ways. Not having to fake "liking" activities in order to get a grade gives them the space to live with these ideas, give them a try, take some risks, and see what happens. The students come to realize the best approach is simply to relax and enjoy it. They are encouraged to take what is useful and tuck the rest away for a rainy day.

Impact

The course was first taught in 1988 to 42 students. The enrollment grew to 51 in 1989, by 1991 it was 60, the capacity of the room it is taught in. This past fall, 110 students attempted to register for the course. This means that it is being sought by the majority of the incoming Masters class (about 130). The course is also popular with other engineering majors and with MBA students.

The Design Division offers a rich array of design courses that have a project-based curriculum. These include year-long courses: Mechatronic Systems Design, Product Design, Smart Product Design; two-quarter sequences: Integrated Design, Marketing and Manufacturing, and Design for Manufacturability; and numerous one-quarter classes in Manufacturing Processes and Design. The faculty involved in these classes report that it is always clear which students have had ME313. Observations include the following: students are more comfortable at the beginning of a project when issues are undefined or confusing; students have less tendency to stick to the very first concept they come up with; students have stronger visualization skills when working with CAD programs (Vellum, ME10, ME30 and MacSurf); students generate and test larger sets of solution candidates; and students possess greatly enhanced communication and presentation skills. Students also tend to be more willing to share ideas and concepts with team members and are more sympathetic to the human concerns in their designs.

Graduates report that being able to quickly sketch thoughts on paper during meetings has an unanticipated result. Industrial colleagues who witness this ability automatically assume the individual to be very creative. This in turn becomes a self–fulfilling prophecy as they are given the more challenging assignments. Graduates also report that they have a significant advantage because they can look at problems from a number of flexible vantage points, to see the big picture as well as zoom in on the details.

Many of the techniques pioneered in this class are showing up in local research and design firms. Examples include mind-mapping, scenario improvisation and story-boarding. I believe there is more to this than the efficacy of the techniques students are bringing with them to the work place. With the introduction of electronics, increasing numbers of products are as much about the design of desired behaviors as they are with the delivery of utilitarian function. Sole reliance on analytical skills will not guarantee engineering success in the increasingly consumer oriented marketplace, nor will it help engineers process the overwhelming amount of information that they will be facing in their careers.

Credits

The creative act invariably involves combining pre-existing ideas. As described above, students are encouraged to take ideas wherever they find them. There is one condition: that they give credit to their source. In this way they will know when they have had a creative idea of their own. In the same spirit, I credit this admonishment to August Coppola of the University of San Francisco and feel the need to mention several others.

Bob McKim created the Visual Thinking class thirty years ago. The term Ambidextrous Thinking did not originate with me. Bob used it as the title of his first chapter in **Experiences in Visual Thinking**. Here he used it in the sense of right and left brain. The terms right and left mode originate with Betty Edwards. For more information about how to teach drawing I recommend her book, **Drawing on the Right Side of the Brain**.

Recognition also goes to the legion of Visual Thinking instructors it has been my pleasure to supervise and work with including Dennis Boyle, Gayle Curtis, and too many others to list here.

I also owe gratitude to my colleagues in the Design Division, particularly Professors Bernard Roth and Douglass Wilde with whom I have offered four Creativity Workshops for Engineering Professors. Our experiences in these workshops are documented in *"Integration of Creativity into the Mechanical Engineering Curriculum,"* a paper published in the 1993 **ASME Resource Guide to Innovation in Design Education**. This publication also contains two other papers which further explore my philosophy regarding Ambidextrous Thinking and are cited in the course reading list provided below.

Conclusion

The gestation of Ambidextrous Thinking has occurred both in a College of Visual and Performing Arts (Syracuse University) and a School of Engineering (Stanford University). Thinking in the former setting is often characterized as being soft and fuzzy, in the latter, cold and hard. These characterizations are impediments to understanding the nature of design process. The central mission of Ambidextrous Thinking is simply to acquaint engineering students with the full range of their human potential in order to encourage a more balanced and potent approach to problem solving. In so doing it demonstrates the important connections between these seeming opposites. As tensegrity sculptor Kenneth Snelson once responded when being described as being an engineer, "Hardening of the categories leads to art failure."

There are few physical barriers to the transmission of similar courses to other institutions. It does benefit from a classroom that can be easily rearranged, but does not require sophisticated technology. The primary impediments are attitudinal. All that is required is the enthusiasm of instructors, the encouragement and support of their colleagues and an administration that believes that engineering is a creative profession.

ME313 Course Reader, List of Selections:

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Weschler, Lawrence, *The Early Lines and the Late Lines*, **Seeing is Forgetting**, University of California Press, © 1982

Whorf, Benjamin Lee, *An American Indian Model of the Universe*, **Language, Thought and Reality**, MIT Press and John Wiley & Sons, © 1956

Fig. 1 Mind-Map of Solution Types for Acrobot Project