Most industrial design work is currently accomplished on screen. The assumption is that, if cost is of no issue, that anything can now be made, thanks to the advances in material and manufacturing technologies. Designers can now sit back, relax, play with computers, create very impressive designs, and be sufficiently convinced of their creative abilities. The days in which designers struggled to find forms with their hands and labor with many prototypes and material possibilities seems to be coming to an end. We are entering a new period in design history where it is no longer necessary for designers to be technically competent, sophisticated, or sensitive as Leonardo, Buckminster Fuller, Walter Gropius, or Charles Eames—whose engagement with materials and making of things, formed the very basis of most of their creative works.

Strangely, such thinking was popular before the modern movement. Designers just needed to design. There were engineers, technicians, and others to do the rest. The modern movement, led by the Bauhaus, radically revered this thinking. It brought together “the making” and “the thinking”—giving rise to one of the greatest revolutions in design history that exploited the new possibilities opened by new material technologies and manufacturing processes.

In the context of the explosive expansion of material and manufacturing possibilities, we see young designers effortlessly exploiting this ever-expanding pool of possibilities to create designs that readily win media appreciation. Why then, should students of design bother with technology?

Technology and Design Education

Design schools are now split in their opinion on the importance of technical education. A good part of the academic community is of the opinion that hands on technical education is no longer essential and that students are better off mastering the new tools of the trade—namely the use of computers.

Many design schools are attaching increasing importance to computer-aided design and reducing the importance of workshops, which are seen as leftovers of the “old school.” While high employability is cited for the increasing emphasis of computer facilities, cost cutting and space shortages are taking a toll on the workshops and facilities that were once seen as essential part of design education. As design education enters the university system, teaching methods are increasingly influenced by design academics some with little or no experience in the practice of design but influence the modernizing process of design education. The older academics with poorer computer skills rarely condemn such changes as they watch in awe the fluency of the younger design students and the fluidity with which they use computers to produce designs that appear to be creative. Computer graphics is becoming the sole technology of interest to students who feel that the mastery of gives them “the edge.”

Why Basic Engineering Is Bad for Design Students
The dominant thinking in many design schools is that students should learn some basic engineering as part of their training in industrial design. Many schools offer watered-down version of the engineering syllabus or expect students to share modules with engineering faculties. This option is unpopular with design students who are admitted to design schools on account of the creative ability and lack the computational abilities of the engineering students. Design students often find themselves in the bottom of engineering classes often dispirited—except for a few, who put in extraordinary effort to stay on top, often at the expense of studio time.

Most engineering courses are designed to build the computational and analytical capacities that are required for engineering students in preparation for further study of engineering. Engineering students however, require “basic” understanding, which is different to the “basic” understanding required by design students who are unlikely to further develop their analytical skills but are likely to build intuitive skills that are useful for design. This is especially true in structural engineering, where the development of intuitive understanding of structural behavior is far more important than analytical abilities for students of architecture.

A New Strategy for Teaching Structural Design

A different approach is proposed for the teaching of structural design to students of architecture and industrial design. The points of differentiation to conventional structural education have been compiled for discussion as:

1. Animals have structural sense
2. To engineer is human
3. Engineering is relatively new

Animals Have Structural Sense

The understanding of structures for many design students has an undesirable links to mathematics, equations, and analytical reasoning. They automatically assume that they will never understand structures if they do not master these abilities. Our proposal is to counter this by pointing out that not only humans but even animals have structural sense. Examples of the design works of termites, beavers, and weaver birds are shown to illustrate their ability to execute complex structures without analytical reasoning. The purpose here is to convince students that very complex structures can be executed with “ground level” feeling for material and structures and such understanding is very much part and parcel of our animal nature. The concept of biological computation is now widely accepted to be superior to computational methods for certain class of problems.

Short video clips of orangutans swinging from branch to branch or squirrels hopping across the tree canopy will convince students of the tremendous understanding of the structural behavior of branches and leaves that are at play at every jump and a “structural miscalculation” could mean death for a monkey. The accuracy and reliability of biological computation is amazing. A video clip of a walking robot will readily illustrate the relative clumsiness of a highly engineered alternative to us.

To Engineer Is Human

The simple act of standing up requires enormous engineering calculations—if we are to implement it mechanically as bipod robots. But we do this effortlessly, due to our innate understanding of force and balance and the terrain that we walking on. Both our hands and feet
have very highly developed feeling for strength, stability, and structural behavior. In addition, our minds have an equally sophisticated model of how objects behave. Such understanding enables us to make a judgment if an object is out of balance or about to fall and this is achieved again without the use of equations. It is what we call intuition. It is primarily with such intuition that the pyramids, the dagobas, mosques, and the churches of the premodern world were built.

Engineering as we know it today did not exist then. Structural behavior is mostly based on material properties and geometry of objects, both of which are things that the eye can perceive, the hand can feel, and the mind can manipulate, without the use of equations.

**Engineering Is Relatively New**

Most of the ancient feats of engineering until premodern times were achieved without “engineering” as we know it today. They were achieved by people who felt and understood engineering principals in nonformal terms. It is only in the late eighteenth century the formal methods began to play a dominant role in design. Moreover, good engineers use analytical reasoning only in the final stages of the design process to proportion the structural members, and to ensure that the designs are safe and reliable under various loading conditions.

Engineering is often understood as a form of analysis by most design students. Very few appreciate the fact that analysis is only one part of engineering that is rapidly being assumed by computers. There are many aspects of engineering that require application of the mind’s processing ability, especially for decisions where analytical procedures are nonexistent. Early stage design decisions fall in this category of problems.

The discussion of “What is science?” helps students to develop a better appreciation of the basis of engineering. The understanding of which will be treated very differently if science is seen as the “refinement of common sense.”

Examples of the great works of architecture and engineering of the premodern world can be used to convince students of design that much can be designed without equations and formulas.

**Building of Intuition**

Specific methods have been developed for the development of structural intuition. A series of exercise have also been developed over many years of teaching

1. Flow of forces
2. Learning by feeling
3. Stop it from bending
4. What materials want to be

This approach focuses of developing structural design abilities. They depart radically from the analytical approach with is most often used in industrial design and architectures school for the teaching of structures.

**Flow of Forces**

Discussions in which students are asked to describe what a force often leads to utter confusion and many interesting propositions—which can be used as a starting point for developing and intuitive understanding of forces.
The classical methods of engineering use a Cartesian framework to analyze forces. These methods are counterintuitive and require mathematical understanding. A more powerful way of visualizing forces may be achieved by using isostatic lines, which indicate the principle direction of compressive and tensional forces. These lines are relatively easy to visualize and can be used to develop an understanding of regions of tension in a structure and is particularly useful for developing an understanding of stress concentration.

Exercises can be assigned for students to draw isostatic lines that approximately represent different loading conditions. Regions of tension and compression should also be identified. This is very useful in teaching the design of reinforced structures where the steel reinforcements need to be laid according to the isostatic lines of tensions.

Stop It from Bending

The art of structural design may also seem as a way of preventing structures from bending. This principle is easily grasped by students who are able to imagine how a simple structure would bend when it is laded. This approach makes it very easy to identify the regions of tensions. Red and blue colors are used to indicate regions of tension and compression; red is used for compression as structures warm up when they are compressed. This method again can also be used for deciding the placement of reinforcement in concrete structures.

Some engineering schools carry out structural testing on models that are often built with stiff materials such as aluminum, steel, or wood. These structures are then load-tested in a loading jig and are loaded gradually until the point at which they suddenly break. While such methods have many merits and can help engineering students develop their analytical skills and identify points of failure (at the weakest point), it does not help develop a comprehensive understanding of the behavior of the entire structure.
A completely different approach is taken where students are given exercises to build structures with extremely low stiffness material such as ordinary sponge (which can be cut with a hot wire). To their annoyance, they find the material to be extremely floppy. They find difficult to make their structures even stand up. In going through such an exercise they develop an understanding as to how structures behave (at all parts of the structure) and learn to design with minimal material. As these structures flop as they are built, they continue to educate the student on the fine art of structural design. Whereas solutions cannot be forced by adding more material (which leads to more weight and more floppiness). An excellent understanding of their bending behavior is developed during the design process and appropriate adjustments and modifications are made as the structures are built. Samples of a diving board made of sponge are shown in Figure 3.

Learning by Feeling

Many assume, that the rational way to design a structure is to draw the design, think about it, analyze it and then if necessary, build models to verify the predicted behavior of the structure.

Sand castles are built differently. The structure emerges out of the very act of building it. An understanding of the structural behavior of sand is intuitively developed as the design progresses. The hands do the thinking here. The same approach may be used for the design of structures. The design of a paper tables illustrated in Figure 4 was developed to develop this skill. Students develop the design by “playing” with paper and by “thinking” with hands. Sketching or drawing is prohibited. Shapes and forms emerge that are structurally sensible and suitable. The phenomenon of emergence, which is now recognized as a critical aspect of the design processes, is at the driving seat.

These structures are also load tested with an ordinary spring balance so that students also develop an understanding of how they fail.
Illustrated in Figure 5, the simple loading jig where the structure is placed on a table with a hole. A wooden board is placed on top of the structure and pulled by a cable that is attached to a spring balance. The nervous student is then made to walk along a plank gradually loading the structure to failure. Such a testing process was found far more exciting than a sophisticated jig with a digital readout of load.

**What Materials Want to Be?**

When students work with their hands and develop the design they also develop a tremendous sensibility to the behavior of materials. They begin to appreciate shapes that materials can be formed into and shapes that materials are reluctant to be in. This sensibility can be further developed using a photo documentation exercise where students are asked to photograph, for example, items designed with sheet materials.

While conventional, especially computer aided designed methods tend to force materials into preconceived shapes. Sensitive hands can shape material in a way that is sympathetic to the material properties.

Many find the material property to be the driving factor or the inspiration for their design. The match between form and material is a critical aspect in the design process that suffers increasingly with the lack of any physical understanding. Works of designers such as Charles Eames may be used to illustrate how material properties can inspire design. The key aim here is to develop the ability to exploit the strengths and weaknesses of different materials as drivers of design.

**Structuring the Projects**

Engineering departments and some schools of architecture make the routine mistake of requesting students to design bridges. Without fail, students bring bridge prototypes for testing that we have all seen. As designs of a typical bridge hovers across the students’ minds, they are relieved from the burden of exercising their structural design ability, which is often the stated purpose of such exercises.
If students are to exercise their structural design ability, they need to be given unique design problems for which the optimal solutions are unknown. The more distant the context is from reality the more creative the students are likely to get. Structural exercises based on film settings, Mars missions, and fictional contexts created out of out science fiction have proven to generate creative structural designs.

Unique design problems force students to think from first principles. The weirdness of the context frees them to explore structurally sensible possibilities uninfluenced by known solutions. The marketing scheme should include a section for the structural efficiency—(the weight carried by the structure/the weight of the structure); this helps students to appreciate that the heaviest solution is not the best solution. The structure that does not fail may also be disqualified (causing much disappointment to students who have built very strong structures) as a case for over design. They can be introduced to the importance of failure, and the different types of failure (gradual and catastrophic) and the factors that may cause it.

Conclusion

The emphasis on technology education seems to be reducing in design schools in a time of unprecedented technological possibilities. The inappropriateness of teaching engineering modules to design students is explained and the need to develop intuitive understanding is emphasized. A teaching strategy that may be used to achieve this is briefly discussed.

It is argued that such intuitive understanding is more readily applied in design. It is demonstrated that a nonanalytical and nonnumerical approach can be used effectively to develop structural design abilities. Such an approach can also unleash the aesthetic aspects of material and manufacturing in shaping design forms. These opportunities and sources of design inspiration are lost in highly computerized design development processes.

In a time where the field of engineering itself is undergoing tremendous changes and the burden of calculations is now borne by computers freeing engineers to explore creative possibilities. Nonengineers may now run complex structural analysis directly off CAD packages. Technical intelligence is no longer associated with the ability to compute. It is now possible to build sound technical knowledge without the need to develop procedural knowledge, which previously formed the bedrock of engineering education.

It is felt that good design no longer requires technical understanding or appreciation of material behavior due to the rapid advances in material and manufacturing technologies. The competence and ability of designers to fully exploit these possibilities certainly appears to be declining in a context where designers are able to easily convince the press, the media and the industrial institutions of their increasing creative capacity.

The compartmentalization of knowledge is a phenomenon that is particularly apparent in many parts of rapidly industrializing Asia where we find “floor full of engineers” and “floor full of designers” educated in the most efficient ways, housed in the same building belonging to the same company rarely able to churn out a truly creative product.

Design education may have something to do with this.