The transition from STEM to STEAM

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Draft of the full paper for presentation at the

ASEE ANNUAL CONVENTION 2020, MONTREAL, CANADA

Title of the paper:

The Transition from S.T.E.M to S.T.E.*A*.M in Engineering Education

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Abstract

Over the last few decades the Accreditation Board for Engineering and Technology (ABET) has emphasized the importance of science, technology, engineering and mathematics (STEM) for the undergraduate engineering curricula. In the recent years, however, another component has been added to it, and that is, *the Arts*, thus transforming STEM to STEAM. The present paper addresses the positive aspects of adding arts to the STEM program, especially in engineering design as well as for engineering practitioners working on a global context. The arts, including literature, music and fine arts, improve our engineering 'reasoning'(left brain) by engaging the intelligence of our emotions (right brain), and hence add that extra touch to our engineering design that customers from different global cultures appreciate. Product design that engages emotions motivate customers to make the final purchase. For the engineers of today, understanding and appreciating another culture is not anymore a choice but a necessity. The slogan of the 1960s, *'think globally but act locally'* is changed today to *'think globally and act globally'.* The transition from STEM to STEAM can have that global impact by leveraging the arts as a way to communicate and connect globally.

Key words: Art, aesthetics, design in engineering, expressive and sensory qualities, form.

Introduction

Aesthetics as a subject of formal study in higher education was first emphasized by John Dewey for the US schools. Dewey referred to art as an experience between the artist, the work of art and its observer [1]. Each time an observer looks at Leonardo da Vinci's Mona Lisa, a new Mona Lisa is born. Art is a continuum from the germination of an idea to the culmination of a complex creation in its supreme form. Aesthetics is a common thread in this process which is essentially a process of the emancipation of truth, whether in fine arts, performing arts, architecture or engineering.

Raymond Loewy, the best known industrial designer of the past century who designed a wide range of products from tooth brushes to ocean liners, Coca Cola bottles to the body of Greyhound buses, ball-point pens to refrigerators, once commented, "Good design keeps the user happy and the aesthetics unoffended."[2]. The late Steve Jobs, the most successful entrepreneur of the recent decades and the founding father of the Apple computer company, remarked in his famous Stanford University

Commencement Speech, " The best companies pay attention to aesthetics. It communicates how they think of themselves, their sense of discipline in engineering, how they run the companies."[3].

Aesthetics in engineering, utilizing objects from nature, is being stressed by modern industrial designers, whether in building architecture or in the design of a shopping mall. Industrial design is in the domain of visual education applicable in fine arts and performing arts. The pioneering works of Leonardo da Vinci are some the earlier examples in the Hellenistic-Judeo-Christian cultures that convey the importance of aesthetic aspects in mechanical design [4]. His extensive note books and sketch pads on all mechanical models, ranging from water pumps to helicopters, put aesthetics on a solid foundation in the domain of design, and reflect the union between beauty and technology, harmony and synthesis, art and artisan's work in a creative endeavor.

Over the past century, engineering was mainly concerned with productivity, service and safety. Words like art and aesthetics were not very common in engineering vocabulary because of a relatively narrow goal adapted by engineering educators. Nevertheless, engineering practitioners were always concerned with the customer's choice, and how that choice rendered a sale or a service. In the consumer culture we live in, the customer's voice gets high-pitched over the production lines, market-oriented and user-friendly designs get popularity due to their demand for sales and service.

Customer's demand is a very respectable parameter in industrial design, from perception to production. This was the key issue during the boom of Japanese automobile industries, and it still persists, currently in the made-in-China market for the rest of the world. Productivity today includes art, aesthetics, beauty-in-simplicity of a marketable product along with the production rate, safety, quality control and reliability in the process of evolution and in the final evaluation of the product, whether a kitchen knife, an automobile or the design of a university cafeteria. Here the user's choice plays a significant role in marketability*. Customers are to productivity as what the voters are to democracy!*

Art and Aesthetics in Engineering Curricula

Introducing art and aesthetics in undergraduate engineering curricula has been supported and justified by many eminent educators in engineering and in other branches of science and technology. Technical drawing courses in the first year of general engineering can be divided into two equivalent components: computer aided drawing, with programming tools such as AutoCad, ProEng, NX, etc., and freehand sketching with some knowledge in descriptive geometry, very often introduced in architectural drawing. These two components are then integrated in a creative way for the actual design of a final product. For example, in automobile industries the car bodies are first drawn on paper, often by commercial artists who are not engineers, and then computer simulation models are implemented by the automobile engineering design specialists to get the best aerodynamic profile as well as its appealing aesthetic appearance. At Queen's University in Canada [5], a market oriented design course is offered in its Mechanical Engineering department where the product prototypes are actually manufactured by the senior year students after a thorough research on marketability of the product including user's opinion. The users are not specialists on aerodynamic profile but want to see an appealing appearance of the product. Many professional painters think that freehand sketching and drawing have positive influence on reasoning and value judgement required to develop "critical thinking" in engineering and in exact sciences.

While each hemisphere of our brain works independently, the right brain being a fountain of feelings and the left brain as the source of reasoning, they share information and often work together through a cord of nerves called *corpus callosum*. One half of the brain helps the other to build an even proportion of reason and emotion [6]. A host of examples can be cited showing that many scientists develop passion in music, such as Einstein, Planck and Bose. Medical doctors spend pastime in painting; mathematicians and physicists, like Bertrand Russell and Werner Heisenberg, are good writers; and wartime heroes, such as Simon Bolivar and Winston Churchill, are prolific authors. These artistic faculties are worth integrating in engineering education and in engineering practice.

Arts and Aesthetics in Engineering Practice

Practicing engineers in design firms are often criticized for not making much room for the artistic and the aesthetic aspects in their innovative designs. Architects and civil engineers are in perpetual conflict on this issue. While an office building must stand strong, it should also be appealing to the eyes of the people, especially those who work inside and around it every day. International tourists don't go to the Taj Mahal or Chichén Itzá to check their constructional strength. Their strength had already passed the test of time centuries ago. People go there to admire the work of art; to appreciate the profound sublime that stands tall beyond the altitude of any cultural relativism [7].

During the time that the Taj Mahal and Chichén Itzá were built, labor was cheaper; feudal system and slavery used to dominate in those ancient empires; and the time and the cost of construction were not the most dominant factors as opposed to today's quick-fix culture [8]. Today, the break-even point between beauty and utility is determined and decided by the time and the cost of construction. Like the palaces in the ancient cities, today's automobiles and airplanes could also be designed for elevated aesthetics plus maximum safety and comfort, but their manufacturing costs would be prohibitively high for the public to buy a car or to ride a plane.

Nevertheless, market conscious engineers, both in design and manufacturing, are increasingly concerned about how a product would appeal to its users in different cultures [9]. In Japanese language there are two very significant words ingrained in its ancient culture and also in its present industrial elite. The words are *wabi* and *sabi:* one for the aesthetic aspect and the other for the practical aspect of an object. In Ginza, the main commercial marketplace and tourist attraction of Tokyo, one finds people walking slowly and watching very simple objects displayed on the glass windows of the souvenir stores, and appreciating the forms: the expressive and sensory qualities of such objects. This is an example of wabi and sabi concept in Japanese culture [9, 10].

There are many other examples to illustrate how the local cultures, and their affinity to aesthetics, affect the sale of international products. Here are a couple of them. Carlsberg, the well-known Danish beer producer installed a factory in Thailand many years ago. After some market studies, the company put a picture of an elephant on the labels of its beer bottles and cans, because elephants are a positive symbol in Thai culture. After a year of very good sales with the new elephant label, Carlsberg updated the design of the label from one to two elephants: a male and a female, meaning a happy couple; and the beer sales doubled! However, after a year or so, the sale declined drastically. The Carlsberg management bosses researched and found that in Thai culture a couple without children for a long time was not a good sign for a family. Therefore, the design was further updated to include a baby elephant in between the couple on the label, and the sales surged back. Another example is from India, a country that is also embedded very deeply in Oriental culture. The first portable solar cooker was designed and built in India many

decades ago. To use that design, one had to take the portable cooker in the open air, in the sunny area for cooking. During those days the social taboo in India wouldn't encourage the housewives of a family to go outside in the open air for cooking. It was simply not in the culture! As such, the solar cooker did not sale well in India but sold well in other foreign markets.

Marketability of a product is dependent as much on its global utility as it is on its local acceptance. For example, Japanese household products when made for the Japanese customers look simpler in their forms or shapes than the same ones manufactured to export in USA and in other Western countries. For example, a portable kitchen item, such as a blender or a juicer made for the Japanese household has a maximum of three or four speed buttons. In contrast, the other brands manufactured to export to Western countries have at least ten speed selection buttons. Whereas in the Oriental tradition whatever is sufficient is good enough, in the Western consumer culture, more and bigger is always better. The impact of local cultural norm is also changing very rapidly due to the effect of globalization at an accelerated pace. Look at the exponentially rising consumption of energy for the household use in China and India!

Art and Aesthetics as a Domain

Artistic and aesthetic qualities are not just confined to the fields of fine arts, performing arts, architecture and engineering. An elegant proof in mathematics or a neat experiment in physics, chemistry or biology is equally aesthetically attractive and beautiful because it is pleasing to our intellect and/or to any one of our five senses: sight, sound, smell, touch and taste (S3T2). Similarly, in an engineering design and manufacture, aesthetics and art are not narrowed down just to the final form of a product but under the entire process from the perception of a concept to its actual production. Aesthetics goes even further, beyond the production of goods and services, and into the elegance of maintaining a product throughout its service life and often in reusing, remanufacturing and recycling (3R). The simple example of replacing a plastic straw and/or a set of plastic cutlery or silverware (spoon, fork and knife) with the ones manufactured with an environmentally benign, biodegradable material, such as with the scraps of jute, bamboo or sugarcane, is equally elegant [11].

Forms that are purely functional in nature also have inherent aesthetic qualities. Poincaré, the famous French mathematician, referring to the possible combinations of mathematical relations, once said, "The most useful combinations are also precisely the most beautiful ones."[12].The wings of a gliding eagle or the flight of an arrow is aerodynamically sound, but it is at the same time, intrinsically beautiful to look at. It is, therefore, the task of an engineer not just to make a product aesthetically pleasing but rather to comprehend the meaning of the assigned design, and communicate it to the customer while taking into account the influence of the aesthetic qualities of a product, such as its form as well as its sensory and expressive qualities.

In the past, engineering education, and also engineering practice to certain extent, ignored this very subtle aspect of aesthetic qualities in designing a product. Nonetheless, there is a recent tendency of change coming from the industries to academia to look at the aesthetic qualities of a product, not just the usefulness vis-à-vis the cost effectiveness; in other words, its economics. Such a change is beneficial for both the educator and the practitioner. For example, combining freehand sketching with computer aided drafting in the freshman engineering courses will introduce artistic senses in human centered design of products and their service. In this particular case, such a change in the curriculum can be brought forth by using the following steps:

1. Recruiting specialists from arts faculty in engineering school;
2. Implementing a one semester course on Aesthetics in Engineering, in the freshman year;
3. Incorporating seminars and workshops on Aesthetics in Engineering in the final year just before graduation.

Final Remarks

Adding art and aesthetics in the undergraduate engineering curricula and programs, thereby transforming S.T.E.M. (Science, Technology, Engineering and Mathematics) to S.T.E.*A*.M., not only creates more awareness in human oriented engineering design and manufacturing but also adds a novel dimension in the personal and professional life of any engineering practitioner. In other professional schools, such as in Law and Medical schools, more emphasis is given on the socio-cultural aspects of the profession. Similarly, medical ethics and legal ethics are compulsory courses in their curricula. In engineering curricula, however, a full compulsory course on engineering ethics is not offered to the undergraduate students. For this reason, during the exams for the engineering license (Professional Engineer or PE license) the recent graduates do not perform well in the areas of engineering ethics and aesthetics.

Inclusion of art and aesthetics adds a new dimension to engineering undergraduate curricula: a human dimension, such as in the area of human oriented engineering design. Unlike our engineering schools, the Law and the Medical schools require just for admission in their programs successful completion of an undergraduate degree in an allied field, such as Biology, Psychology or Chemistry for Medical schools and Sociology, Humanities or Anthropology for Law schools. Their very first university degrees are also at a Doctorate level, namely, M.D and LL.D. Thus their first university degree is equivalent to our terminal degree (Ph.D. or D. Eng.)!

In order to cooperate or compete with the medical doctors and lawyers, engineering graduates need to be more matured. Adding art and aesthetics to our undergraduate engineering curricula will help to bridge this professional gap.

Acknowledgement

I wish to express sincere thanks to my daughter, Dr. Anyana Banerjee, for editing this English version of the article.

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