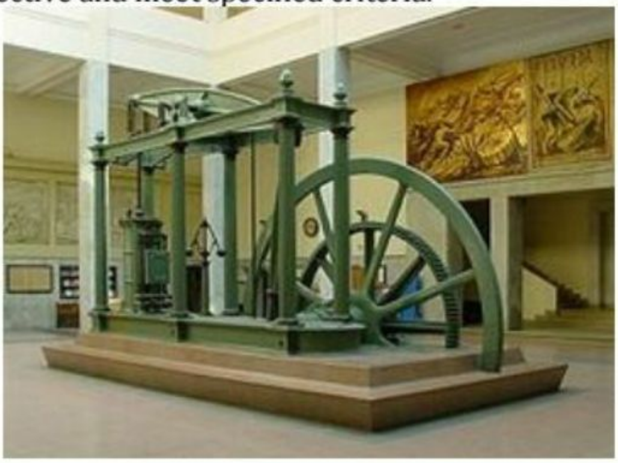
21GNH101J- PHILOSOPHY OF ENGINEERING
UNIT-1

Definition:

"Engineering is the discipline and profession of applying technical and scientific knowledge and utilizing natural laws and physical resources in order to design and implement materials, structures, machines, devices, systems, and processes that safely realize a desired objective and meet specified criteria."



The American Engineers' Council for Professional Development (ECPD, the predecessor of ABET) has defined engineering as follows:

"The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property."

One who practices engineering is called an **engineer**, and those licensed to do so may have more formal designations such as European Engineer, Professional Engineer, Chartered Engineer, or Incorporated Engineer. The broad discipline of engineering encompasses a range of more specialized sub disciplines, each with a more specific emphasis on certain fields of application and particular areas of technology.

History

The *concept* of engineering has existed since ancient times as humans devised fundamental inventions such as the pulley, lever, and wheel. Each of these inventions is consistent with the modern definition of engineering, exploiting basic mechanical principles to develop useful tools and objects.

The term engineering itself has a much more recent etymology, deriving from the word engineer, which itself dates back to 1325, when an engine'er (literally, one who operates an engine) originally referred to a constructor of military engines.

The word "engine" itself is of even older origin, ultimately deriving from the Latin *ingenium* (c. 1250), meaning "innate quality, especially mental power, hence a clever invention."

Later, as the design of civilian structures such as bridges and buildings matured as a technical discipline, the term civil engineering entered the lexicon as a way to distinguish between those specializing in the construction of such non-military projects and those involved in the older discipline of military engineering.

Ancient Era

The Acropolis and the Parthenon in Greece, the Roman aqueducts, Via Appia and the Colosseum, the Hanging Gardens of Babylon, the Pharos of Alexandria, the pyramids in Egypt, Teotihuacán and the cities and pyramids of the Mayan, Inca and Aztec Empires, the Great Wall of China, among many others, stand as a testament to the ingenuity and skill of the ancient civil and military engineers.

The earliest civil engineer known by name is Imhotep. As one of the officials of the Pharaoh, Djosèr, he probably designed and supervised the construction of the Pyramid of Djoser (the Step Pyramid) at Saqqara in Egypt around 2630-2611 BC. He may also have been responsible for the first known use of columns in architecture.

Ancient Greece developed machines in both in the civilian and military domains. The Antikythera mechanism, the earliest known model of a mechanical computer in history, and the mechanical inventions of Archimedes are examples of early mechanical engineering. Some of Archimedes' inventions as well as the Antikythera mechanism required sophisticated knowledge of differential gearing or epicyclic gearing, two key principles in machine theory that helped design the gear trains of the Industrial revolution and are still widely used today in diverse fields such as robotics and automotive engineering.

Chinese and Roman armies employed complex military machines including the Ballista and catapult. In the Middle Ages, the Trebuchet was developed.

Middle Era

An Iraqi by the name of al-Jazari helped influence the design of today's modern machines when sometime in between 1174 and 1200 he built five machines to pump water for the kings of the Turkish Artuqid dynasty and their palaces. The double-acting reciprocating piston pump was instrumental in the later development of engineering in general because it was the first machine to incorporate both the connecting rod and the crankshaft, thus, converting rotational motion to reciprocating motion.

Renaissance Era

The first electrical engineer is considered to be William Gilbert, with his 1600 publication of De Magnete, who was the originator of the term "electricity".

The first steam engine was built in 1698 by mechanical engineer Thomas Savery. The development of this device gave rise to the industrial revolution in the coming decades, allowing for the beginnings of mass production.

With the rise of engineering as a profession in the eighteenth century, the term became more narrowly applied to fields in which mathematics and science were applied to these ends. Similarly, in addition to military and civil engineering the fields then known as the mechanic arts became incorporated into engineering.

Modern Era

Electrical Engineering can trace its origins in the experiments of Alessandro Volta in the 1800s, the experiments of Michael Faraday, Georg Ohm and others and the invention of the electric motor in 1872. The work of James Maxwell and Heinrich Hertz in the late 19th century gave rise to the field of Electronics. The later inventions of the vacuum tube and the transistor further accelerated the development of Electronics to such an extent that electrical and electronics engineers currently outnumber their colleagues of any other Engineering specialty.

The inventions of Thomas Savery and the Scottish engineer James Watt gave rise to modern Mechanical Engineering. The development of specialized machines and their maintenance tools during the industrial revolution led to the rapid growth of Mechanical Engineering both in its birthplace Britain and abroad.

Chemical Engineering, like its counterpart Mechanical Engineering, developed in the nineteenth century during the Industrial Revolution. Industrial scale manufacturing demanded new materials and new processes and by 1880 the need for large scale production of chemicals was such that a new industry was created, dedicated to the development and large scale manufacturing of chemicals in new industrial plants. The role of the chemical engineer was the design of these chemical plants and processes.

Aeronautical Engineering deals with aircraft design while Aerospace Engineering is a more modern term that expands the reach envelope of the discipline by including spacecraft design. Its origins can be traced back to the aviation pioneers around the turn of the century from the 19th century to the 20th although the work of Sir George Cayley has recently been dated as being from the last decade of the 18th century. Early knowledge of aeronautical engineering was largely empirical with some concepts and skills imported from other branches of engineering. Only a decade after the successful flights by the Wright brothers, the 1920s saw extensive development of aeronautical engineering through development of World War I military aircraft. Meanwhile, research to provide fundamental background science continued by combining theoretical physics with experiments.

Methodology

Engineers apply the sciences of physics and mathematics to find suitable solutions to problems or to make improvements to the status quo. More than ever, Engineers are now required to have knowledge of relevant sciences for their design projects, as a result, they keep on learning new material throughout their career. If multiple options exist, engineers weigh different design choices on their merits and choose the solution that best matches the requirements. The crucial and unique task of the engineer is to identify, understand, and interpret the constraints on a design in order to produce a successful result. It is usually not enough to build a technically successful product; it must also meet further requirements. Constraints may include available resources, physical, imaginative or technical limitations, flexibility for future modifications and additions, and other factors, such as requirements for cost, safety, marketability, productibility, and serviceability. By understanding the constraints, engineers derive specifications for the limits within which a viable object or system may be produced and operated.

Problem solving

Engineers use their knowledge of science, mathematics, and appropriate experience to find suitable solutions to a problem. Engineering is considered a branch of applied mathematics and science. Creating an appropriate mathematical model of a problem allows them to analyze it (sometimes definitively), and to test potential solutions. Usually multiple reasonable solutions exist, so engineers must evaluate the different design choices on their merits and choose the solution that best meets their requirements.

There exists an overlap between the sciences and engineering practice; in engineering, one applies science. Both areas of endeavor rely on accurate observation of materials and phenomena. Both use mathematics and classification criteria to analyze and communicate observations. Scientists are expected to interpret their observations and to make expert recommendations for practical action based on those interpretations.

Relation between Arts, Mathematics, Science, Technology and Engineering

Art:

Art is a wide range of human activities (or the products thereof) that involve creative imagination and an aim to express technical proficiency, beauty, emotional power, or conceptual ideas. The three classical branches of visual art are painting, sculpture, and architecture. The creative arts are often divided into more specific categories, typically along perceptually distinguishable categories such as media, genre, styles, and form.

Art form refers to the elements of art that are independent of its interpretation or significance. It covers the methods adopted by the artist and the physical composition of the artwork, primarily non-semantic aspects of the work such as color, contour, dimension, medium, melody, space, texture, and value. Form may also include visual design principles, such as arrangement, balance, contrast, emphasis, harmony, proportion, proximity, and rhythm. In general there are three schools of philosophy regarding art, focusing respectively on form, content, and context.

Art has had a great number of different functions throughout its history, making its purpose difficult to abstract or quantify to any single concept. This does not imply that the purpose of Art is "vague", but that it has had many unique, different reasons for being created. Some of these functions of Art are provided in the following outline. The different purposes of art may be grouped according to those that are non-motivated, and those that are motivated

Non-motivated functions

The non-motivated purposes of art are those that are integral to being human, transcend the individual, or do not fulfill a specific external purpose. In this sense, Art, as creativity, is something humans must do by their very nature (i.e., no other species creates art), and is therefore beyond utility.[67]

1. **Basic human instinct for harmony, balance, rhythm.** Art at this level is not an action or an object, but an internal appreciation of balance and harmony (beauty), and therefore an aspect of being human beyond utility.
2. **Experience of the mysterious.** Art provides a way to experience one's self in relation to the universe. This experience may often come unmotivated, as one appreciates art, music or poetry.
3. **Expression of the imagination.** Art provides a means to express the imagination in non-grammatic ways that are not tied to the formality of spoken or written language. Unlike words, which come in sequences and each of which have a definite meaning, art provides a range of forms, symbols and ideas with meanings that are malleable.
4. **Ritualistic and symbolic functions.** In many cultures, art is used in rituals, performances and dances as a decoration or symbol. While these often have no specific utilitarian (motivated) purpose, anthropologists know that they often serve a purpose at the level of meaning within a particular culture. This meaning is not furnished by any one individual, but is often the result of many generations of change, and of a cosmological relationship within the culture.

Motivated functions

Motivated purposes of art refer to intentional, conscious actions on the part of the artists or creator. These may be to bring about political change, to comment on an aspect of society, to convey a specific emotion or mood, to address personal psychology, to illustrate another discipline, to (with commercial arts) sell a product, or simply as a form of communication.[67][72]

1. **Communication.** Art, at its simplest, is a form of communication. As most forms of communication have an intent or goal directed toward another individual, this is a motivated purpose. Illustrative arts, such as scientific illustration, are a form of art as communication. Maps are another example. However, the content need not be scientific. Emotions, moods and feelings are also communicated through art.
2. **Art as entertainment**. Art may seek to bring about a particular emotion or mood, for the purpose of relaxing or entertaining the viewer. This is often the function of the art industries of Motion Pictures and Video Games.
3. **The Avant-Garde. Art for political change.** One of the defining functions of early 20th-century art has been to use visual images to bring about political change. Art movements that had this goal—Dadaism, Surrealism, Russian constructivism, and Abstract Expressionism, among others—are collectively referred to as the *avant-garde* arts.

4. **Art as a "free zone"**, removed from the action of the social censure. Unlike the avant-garde movements, which wanted to erase cultural differences in order to produce new universal values, contemporary art has enhanced its tolerance towards cultural differences as well as its critical and liberating functions (social inquiry, activism, subversion, deconstruction ...), becoming a more open place for research and experimentation.
5. **Art for social inquiry, subversion or anarchy.** While similar to art for political change, subversive or deconstructivist art may seek to question aspects of society without any specific political goal. In this case, the function of art may be simply to criticize some aspect of society.
6. **Art for social causes.** Art can be used to raise awareness for a large variety of causes. A number of art activities were aimed at raising awareness of autism, cancer, human trafficking, and a variety of other topics, such as ocean conservation, human rights in Darfur, murdered and missing Aboriginal women, elder abuse, and pollution. Trashion, using trash to make fashion, practiced by artists such as Marina DeBris is one example of using art to raise awareness about pollution.
7. **Art for psychological and healing purposes.** Art is also used by art therapists, psychotherapists and clinical psychologists as art therapy. The Diagnostic Drawing Series, for example, is used to determine the personality and emotional functioning of a patient. The end product is not the principal goal in this case, but rather a process of healing, through creative acts, is sought.
8. **Art for propaganda, or commercialism.** Art is often utilized as a form of propaganda, and thus can be used to subtly influence popular conceptions or mood. In a similar way, art that tries to sell a product also influences mood and emotion. In both cases, the purpose of art here is to subtly manipulate the viewer into a particular emotional or psychological response toward a particular idea or object.[91]
9. **Art as a fitness indicator.** It has been argued that the ability of the human brain by far exceeds what was needed for survival in the ancestral environment. One evolutionary psychology explanation for this is that the human brain and associated traits (such as artistic ability and creativity) are the human equivalent of the peacock's tail. The purpose of the male peacock's extravagant tail has been argued to be to attract females (see also Fisherian runaway and handicap principle). According to this theory superior execution of art was evolutionarily important because it attracted mates.

Mathematics:

Mathematics, the science of structure, order, and relation that has evolved from elemental practices of counting, measuring, and describing the shapes of objects. It deals with logical reasoning and quantitative calculation, and its development has involved an increasing degree of idealization and abstraction of its subject matter. Since the 17th century, mathematics has been an indispensable adjunct to the physical sciences and technology, and in more recent times it has assumed a similar role in the quantitative aspects of the life sciences.

In many cultures—under the stimulus of the needs of practical pursuits, such as commerce and agriculture—mathematics has developed far beyond basic counting. This growth has been greatest in societies complex enough to sustain these activities and to provide leisure for contemplation and the opportunity to build on the achievements of earlier mathematicians.

All mathematical systems (for example, Euclidean geometry) are combinations of sets of axioms and of theorems that can be logically deduced from the axioms. Inquiries into the logical and philosophical basis of mathematics reduce to questions of whether the axioms of a given system ensure its completeness and its consistency.

Science:

Science (from Latin *scientia* 'knowledge') is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the world.

The earliest roots of science can be traced to Ancient Egypt and Mesopotamia in around 3000 to 1200 BCE. Their contributions to mathematics, astronomy, and medicine entered and shaped Greek natural philosophy of classical antiquity, whereby formal attempts were made to provide explanations of events in the physical world based on natural causes. After the fall of the Western Roman Empire, knowledge of Greek conceptions of the world deteriorated in Western Europe during the early centuries (400 to 1000 CE) of the Middle Ages, but was preserved in the Muslim world during the Islamic Golden Age. The recovery and assimilation of Greek works and Islamic inquiries into Western Europe from the 10th to 13th century revived "natural philosophy", which was later transformed by the Scientific Revolution that began in the 16th century[10] as new ideas and discoveries departed from previous Greek conceptions and traditions. The scientific method soon played a greater role in knowledge creation and it was not until the 19th century that many of the institutional and professional features of science began to take shape; along with the changing of "natural philosophy" to "natural science."

Modern science is typically divided into three major branches[19] that consist of the natural sciences (e.g., biology, chemistry, and physics), which study nature in the broadest sense; the social sciences (e.g., economics, psychology, and sociology), which study individuals and societies; and the formal sciences (e.g., logic, mathematics, and theoretical computer science), which deal with symbols governed by rules. There is disagreement, however, on whether the formal sciences actually constitute a science as they do not rely on empirical evidence. Disciplines that use existing scientific knowledge for practical purposes, such as engineering and medicine, are described as applied sciences.

Technology:

The word "technology" can also be used to refer to a collection of techniques. In this context, it is the current state of humanity's knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants; it includes technical methods, skills, processes, techniques, tools and raw materials. When combined with another term, such as "medical technology" or "space technology," it refers to the state of the respective field's knowledge and tools. "State-of-the-art technology" refers to the high technology available to humanity in any field.

Technology can be viewed as an activity that forms or changes culture.[14] Additionally, technology is the application of mathematics, science, and the arts for the benefit of life as it is known. A modern example is the rise of communication technology, which has lessened barriers to human interaction and as a result has helped spawn new subcultures; the rise of cyberculture has at its basis the development of the Internet and the computer. As a cultural activity, technology predates both science and engineering, each of which formalize some aspects of technological endeavor.

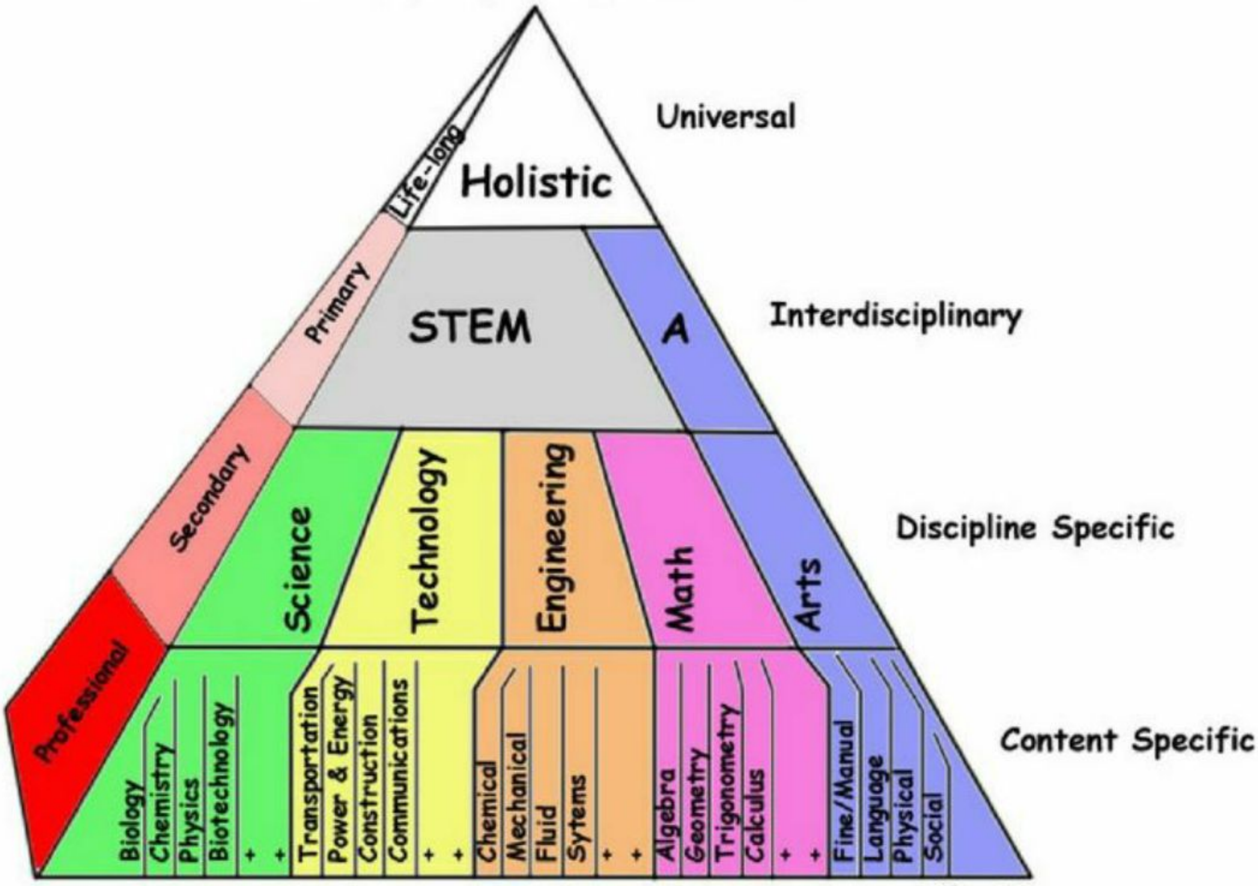
Science, engineering, and technology

The distinction between science, engineering, and technology is not always clear. Science is systematic knowledge of the physical or material world gained through observation and experimentation.[16] Technologies are not usually exclusively products of science, because they have to satisfy requirements such as utility, usability, and safety.

Engineering is the goal-oriented process of designing and making tools and systems to exploit natural phenomena for practical human means, often (but not always) using results and techniques from science. The development of technology may draw upon many fields of knowledge, including scientific, engineering, mathematical, linguistic, and historical knowledge, to achieve some practical result.

Technology is often a consequence of science and engineering, although technology as a human activity precedes the two fields. For example, science might study the flow of electrons in electrical conductors by using already-existing tools and knowledge. This new-found knowledge may then be used by engineers to create new tools and machines such as semiconductors, computers, and other forms of advanced technology. In this sense, scientists and engineers may both be considered technologists; the three fields are often considered as one for the purposes of research and reference.

STEAM Pyramid:



STEM education was introduced in order to improve competitiveness in Science and Technology in the United States in 2003. STEM teaches science, technology, engineering, mathematics in an integrated way. In 2007 George yakman has announced STEAM in addition art to the STEM. Yakman said by the STEAM education we can increase their relevance to real life and interests. Many education scholars into a unified art in STEM education, said be STEAM. Out from the dichotomous thinking such that science of conventional is logical and art is not logical, STEAM is to foster creative human resources by integrating STEM and art. Science provides a methodological tool in the art and art provides creative model in the development of science. Science uses imagination and emotion, thinking that the power of visualization principles of art and art uses scientific discoveries and principles of science.

The STEAM pyramid was built to help educators and students see the subjects involved in STEAM and the learning approaches practiced at each level. Understanding the framework is important for teachers to provide appropriate teaching plans and activities for their students. As for the students, they can clearly know the subject in each field. For example, the subject science fields involved are biology, chemistry, physics, biochemistry, geoscience and so on.

This knowledge allows students to know what fields they are interested in, the potential of each field and they can make plans for their future.

STEAM education is a complete educational model to be applied in teaching and learning in primary schools especially in first year science subjects. According to past studies, there are many benefits we derive from STEAM education. Among the benefits of STEAM education are:

STEAM can attract students in science subjects. STEAM education can increase students' interest in science subjects in primary schools. This is because STEAM approaches such as using experimental teaching methods, simulations, projects, technology and visits allow students to learn through experience.

The value of collaboration is the value of art that is the ability to collaborate and interact in groups. Therefore, STEAM is important in ensuring that creative students can be born and can solve problems while they work the class. These skills will be able to guarantee in an effort to provide a multi-skilled workforce in the 22nd century.

In STEAM education, one of the key features is to encourage collaborative teaching. Collaboration in the teaching and learning process can train students to be tolerant, cooperative, always respect others and the environment and understand the concept of socializing.

STEAM can help improve social relationships among students through active learning through questioning and discussion activities. Transdiscipline through STEAM can help solve problems in society. Various inventions such as technological and scientific innovations can ease the burden of society while doing work. For example, humans use robots to perform daily tasks such as sweeping, sending and picking up goods and discussing. These changes are a result of STEAM education.

STEAM with the arts can help strengthen the foundation of science. Pupils use a variety of ways to produce their products based on science concepts through art. From this opinion, the researchers found that the arts can help improve STEM achievement at the primary school level.

Art skills are directly related to science teaching skills especially of students in primary schools. The combination of arts and STEM has produced a more perfect teaching known as STEAM. Through STEAM students can learn science in a more interesting, fun and easy way to remember science facts

Desired Attributes of an Engineer:

Engineers are the inventors, designers, analysers and builders of our modern age. They create the machines, structures and systems we use on a daily basis. The constrains of physics, the confines of the manufacturing technology of the modern age, the limitations imposed by current material properties, requirements in terms of health and safety and cost: all of these are things that engineers must take into account when designing whatever it is they're working on. Luckily, engineers are trained to recognise and solve these problems; but in *order* to recognise and solve them, engineers have to have a very particular set of skills, skills acquired over a long career, skills that make engineers a nightmare for anything these problems might throw at them. But what are these skills?

1. Teamwork

2. Continuous learning

3. Creativity

4. Problem solving

5. Analytical ability

6. Communication skills

7. Logical thinking

8. Attention to detail

9. Mathematical ability

10. Leadership

1. Teamwork

Teamwork drives the successful completion of a project. No one can complete a project on their own; they need others to contribute. There are functions that can be performed individually, but more often than not, an engineer will be part of a bigger team, and must be able to work well therein.

Courtesy and tact goes a long way in building team trust. Project details are often presented to managers and customers, and these interactions may become confrontational. An engineer must understand everybody's position and should not feel attacked, keep team members informed, and always present facts accurately.

2. Continuous learning

Technology and methodologies are constantly changing, and nowhere is this truer than in engineering. A successful engineer is able to keep abreast of the latest technological updates and capable of delivering the best value and quality work.

Engineers are curious by nature. They are interested in understanding how things work. This gives them a natural aptitude for learning and allows them to continue building their knowledge. In modern times technology changes quickly, so it is critical to constantly learn and stay up to date. Successful engineers never assume they know everything.

3. Creativity

It may sound clichéd, but successful engineers have an innate ability to 'think outside the box'. The engineering industry runs on the ability to creatively solve problems. Engineers able to bring passion, creative solutions and big ideas to the table are more valuable as businesses depend on creativity to efficiently resolve problems or improve the efficiency of existing systems and processes. Simultaneously, a successful engineer needs to be attentive to practicality when proposing a creative solution - which entails being creative in itself.

4. Problem solving

Any project, no matter how big or small, will face problems. An engineer must be able to effectively address these as they arise. They must meticulously study the problem, fully understand the impact it has on the project, and then apply their analytical skills in a methodical and efficient way in order to identify the root cause.

To effectively solve problems an engineer must also have the ability to truly listen to the problem 'owner'. By attentively listening an engineer is able to fully comprehend what the problem consists of and provide solutions from a well-informed standpoint.

5. Analytical ability

The ability to effectively solve problems goes hand-in-hand with the ability to properly analyse problems. Engineers are required to think analytically in order to create solutions. Analysing a project scope or product specification ensures that an engineer fully understands the relevant requirements and efficiently applies resources to achieve the optimal outcome. Various methodologies may have to be tested before committing resources to guarantee a successful solution.

6. Communication skills

Communication is more than reading, writing, speaking or listening. For an engineer it means the ability to not only understand technical complexities, but the ability to succinctly and effectively translate technical jargon into layman's terms without patronising others.

Engineers communicate with people at many different levels, from unskilled workers to directors. The ability to communicate in a respectful, clear and concise manner is critical to ensure that the core message is effectively relayed.

7. Logical thinking

To fully comprehend complex systems an engineer must understand all aspects of the system. An engineer must know how the system works, what can go wrong and how to fix it. This requires an ability to think logically, and evaluate and understand each element that makes it up.

Successful engineers are naturally curious and always looking for ways to make things better. They have to be able to analyse an existing system to understand how the different pieces work individually and as a unit.

8. Attention to detail

Successful engineers pay meticulous attention to the smallest of details. They understand that the slightest error may cause a structure to fail, a system to malfunction or software to glitch. The smallest error can cost a significant amount of money or, in some cases, be fatal.

Complex projects may have a large number of steps to complete and having one tiny thing out of place may delay an entire project. Being detail orientated during the planning and development phases is pivotal for overall success. Successful engineers know that their success depends on their ability to control the details. Never assume something is too small or insignificant to care about.

9. Mathematical ability

Software has replaced almost all of the complex derivative equations engineers used to do manually. Even though engineers are no longer required to do these complex calculations themselves it doesn't mean that, to be successful, they don't have to possess excellent mathematical skills.

Engineers must be well-versed in trigonometry and calculus in order to use software packages and be able to interpret the results derived from them. They must be able to understand the type of calculations required to ensure the correct type of simulation is performed, and that models are correctly defined when performing simulations.

10. Leadership

Leadership ability encompasses many of the characteristics already mentioned on this list. But being a leader is far more than this. It also requires excellent interpersonal skills and an ability to inspire and motivate others to drive a team to achieve success.

Sure, an successful engineer needs to tick all the engineering hard skills boxes listed above, like maths knowledge and analytical ability - but they also need well-developed soft skills so they can smoothly perform non-technical duties. People who are charismatic, articulate and friendly are normally well-liked, and are able to easily garner support.

ABET EC 2000 Engineering Accreditation Criteria (Criterion 3) In 1996 ABET (formerly the Accreditation Board for Engineering and Technology), the influential engineering accreditation board, adopted a new set of standards for undergraduate engineering education, called Engineering Criteria 2000 (EC2000) (ABET, 2014a). EC2000 shifted the focus of undergraduate engineering accreditation from lists of required courses to eleven learning outcomes. These outcomes are summarized below in Table 1:

a. An ability to apply knowledge of mathematics, science, and engineering appropriate to discipline.
b. An ability to design and conduct experiments, as well as to analyze and interpret data
c. An ability to design a system, component, or process to meet desired needs
d. The ability to function on multi-disciplinary teams
e. An ability to identify, formulate, and solve engineering problems
f. An understanding of professional and ethical responsibility
g. An ability to communicate effectively
h. The broad education necessary to understand the impact of engineering

solutions in a global and societal context
i. A recognition of the need for and an ability to engage in life-long learning
j. A knowledge of contemporary issues
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Table 1: ABET Engineering Criteria EC2000.

In addition to topics long-associated with engineering practice such as mathematics, science, design, experimentation, and use of modern engineering tools, the new ABET criteria stressed issues of particular relevance to technological literacy. In the new criteria, ABET required programs to show that they teach engineering students to recognize the relationship between technology and society and to recognize "the impact of engineering solutions in a global and societal context." The EC2000 criteria also included an emphasis on the ethical responsibilities of engineers. To keep accreditation of their degree programs, institutions must show that these topics are covered, must assess and evaluate student learning, and work to continuously improve instruction in these areas. Similar requirements were included in new ABET standards for baccalaureate engineering technology degree programs (ABET, 2014b).

ITEA(now ITEEA) "Standards for Technological Literacy"

In 2000 what was then called the International Technology Education Association (ITEA) published Standards for Technological Literacy: Content for the Study of Technology (International Technology Education Association, 2000). The intent of the ITEA effort was to encourage educational curricula providing technological literacy to all K-12 students. The ITEA standards project was a wide-reaching effort. More than a hundred reviewers from engineering, K-12 education, and the sciences, participated in the process. The project represents one of the first large-scale standards efforts in the US to specifically address the topic of technology independently from science and mathematics. Given the magnitude of the effort, it is not surprising to find that the resulting ITEA 2000 Standards are comprehensive in scope. The standards consist of five major categories subdivided into 20 specific standards. The five main categories used to by the ITEA to define technological literacy are listed in Table 2.

1. Understanding the Nature of Technology.
2. Understanding of Technology and Society.
3. Understanding of Design.
4. Abilities for a Technological World.
5. Understanding of the Designed World

Table 2: ITEA Categories Defining Technological Literacy

The ITEA standards enumerate a thorough set of features that characterize an understanding of technology. The nature of technology includes abilities needed by K-12 students to distinguish technology from other aspects of their environment. The importance of examining the interaction between technology and the society responsible for its creation is highlighted. The methods used to create technology through a rational design process are considered as a separate area of the standards. Also included are specific capabilities or competencies such as selecting technological products appropriate for a specific set of requirements, or knowledge of how to carryout problem-solving in technological systems. The Designed World category of the standards identifies certain domains of the human-built world as topics of study such as communication, manufacturing, and energy technologies.

National Academy of Engineering: "Technically Speaking" and "Tech Tally"

During the same time period that ITEA was addressing technological literacy in the K-12 realm, the National Academy of Engineering (NAE) started an initiative developing awareness of the importance of public understanding of technology. This lead to the publication of Technically Speaking in 2002 (Pearson and Young, 2002) and Tech Tally in 2006 (Garmire and Pearson, 2006). Technically Speaking was intended to reach a wide audience. This NAE initiative sought to achieve recognition that technology consists of the broad array of products and processes that are created by engineers to satisfy human needs and wants. Technically Speaking also attempted to clarify that engineering and science are distinct but related activities. Tech Tally surveyed the state-of-the-art in measuring the understanding of technology. The combination of Technically Speaking and Tech Tally defined technological literacy in terms of four content areas of technological literacy. The four content areas of technological knowledge are defined and listed in Table 3. These are: technology and society; design; products and systems; and characteristics, concepts, and connections. Technically Speaking also envisioned another dimension of technological literacy related to the level of cognitive engagement in each content area. This knowledge in the technical realm was then seen as categorized in a series of increasingly sophisticated levels consisting of knowledge, capabilities, and ways of thinking and acting.

1. Technology and Society
2. Design
3. Products and Systems
4. Characteristics, Concepts, and Connections

Table 3: National Academy of Engineering Technological Literacy Content Areas.

At this point an approximate convergence can be seen between the National Academy of Engineering and International Technology Education Association efforts regarding the major areas that define technological literacy or the broad understanding of the diverse array of products and processes that are created by people to satisfy human needs and wants. Technological literacy is viewed as the four main areas identified by the correspondence between the two groups. One area is the relationship between technology and society. A second area is the design process used in the creation of technology and relations to other disciplines. The third area is the general nature and character of technology. The fourth area concerns the specific domains or broad areas of technology such as manufacturing, communications, medical technology, and energy.

Engineering standards for K – 12 Education

The attention given to technological innovation as central to economic competiveness, and the association of engineering with technological innovation contributed to a recognition that some introduction to engineering should be included as part of the K-12 curriculum in the United States. A perceived shortage of engineers was attributed in part to the lack of familiarity with engineering as a career option at a time when middle and high school student's aspirations for the future are being formed. Coincident with these developments were episodes of significant national publicity for FIRST a high school robotics competition with a name coined to promote STEM careers (For Inspiration and Recognition of Science and Technology, FIRST, 2014). In this era consensus grew among educational policy makers that it would be appropriate to include engineering education in the K-12 curriculum rather than waiting until the undergraduate years. Project Lead the Way has developed curriculum at the middle and high school levels and has extensive training programs for teachers. In 2013, the company brought out a program for K-5, giving them a full K-12 curriculum. The company reports that their curriculum has been adopted by over 5,000 programs in across the United States (Project Lead the Way, 2014). The Museum of Science in Boston has developed a National Center for Technological Literacy. According to their website, the center has developed a K-12 program, the Gateway Project, has museum and online programs, and has been active in developing state standards, including the first statewide standards in Massachusetts (National Center for Technological Literacy, 2014). These developments lead to the discussion of what standards might be appropriate for engineering when taught at the K-12 level. The National Academy of Engineering considered the idea of engineering standards for K-12 students (National Academy of Engineering, 2010). In the process this work has outlined what is engineering and what type of engineering capabilities are broadly applicable across the entire K-12 population. In effect, K-12 engineering standards begin to serve as a working definition of engineering literacy. Discussions about national standards for engineering by the NAE Committee on Standards for K-12 Engineering converged on three broad areas. While the committee chose not to press for engineering standards in K-12 education at that time, the committee did identify some general principles for K-12 Engineering Education. These principles are summarized in Table 4.

1. K-12 Engineering Education should emphasize engineering design.
2. K-12 Engineering Education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills.
3. K-12 Engineering Education should promote engineering habits of mind

Table 4: General Principles for K-12 Engineering Education, NAE Committee on Standards for K-12 Engineering

Engineering habits of mind were defined to include "essential skills for citizens in the 21st century" including creativity, systems thinking, collaboration, communication and attention to ethical considerations. At this point in time the general principles of K-12 engineering standards did not include specific reference to the topic of technology and society. A key point of the K-12 standards is the centering of engineering literacy for all students on the process of design. The design process is identified as the essential characteristic of engineering. The definitions of engineering literacy were coincident with familiarity with the process used by engineers to create technological products, process, and systems.

Next Generation Science Standards

The Next Generation Science Standards (NGSS) released in April 2013 finds topics of engineering and technological literacy interwoven with traditional science topics. The NGSS were the result of a collaboration between twenty six US states (Next Generation Science Standards, 2013). The standards draw heavily from work of the National Research Council Committee on New K-12 Science Education Standards (National Academy of Science, 2012), and are based on three dimensions advocated by the committee: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. While the organization of the standards is complex: five of 13 major topics are listed in Table 5.

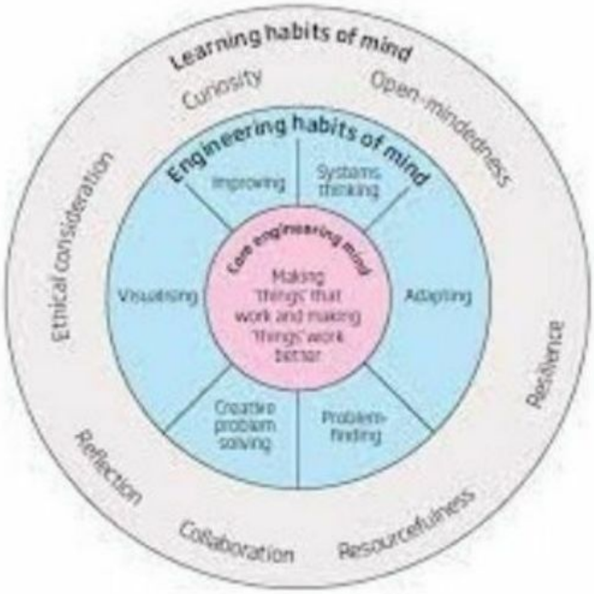
1. Science and Engineering Practices
2. Crosscutting Concepts
3. Nature of Science 4. Engineering Design
5. Science, Technology, Society and the Environmen

Table 5: Some Major Topics in the Next Generation Science Standards.

Perhaps the most significant development in these standards is the overt and deliberate effort to convey parity between engineering and science in the standards. In addition, the relationships and reciprocal interactions between engineering, technology, and science on society and the natural world feature prominently in the standards.

Engineering Habits of Mind:

Engineering habits of mind were defined to include "essential skills for citizens in the 21st century" including creativity, systems thinking, collaboration, communication and attention to ethical considerations.



When asked the question 'What do engineers do?' our respondents repeatedly stressed that the desire to 'make things that work' or make things 'work better' was the driving force behind what made them become engineers:

Great engineers constantly challenge the 'norm' and are always looking for improvements and innovation in everything they do. They are never fully satisfied with a product or outcome and will try and modify and improve what they have designed or produced to make it better.

We also found considerable consensus among all respondents that our six EHoM were appropriate descriptors for the characteristic ways in which engineers think and act when faced with challenging problems relating to making and improving things. However, despite an overall agreement on the importance of all six, there were some differences of opinion on the relative importance of each at different education levels.

Systems thinking was universally supported as an important EHoM but was felt to be particularly difficult to cultivate, perhaps being of most importance the more advanced the level of engineering became:

The idea that everything you do sort of builds to making you into a rounded, capable person who can link all the knowledge together is the one that perhaps we could work on.

Problem-finding was also regarded as a sophisticated EHoM and more likely to be exercised by experienced engineers or by learners after they had successfully built up a repertoire of approaches to problem solving based on given problems:

Some respondents wondered whether 'finding' was the best term, suggesting 'formulating' or 'framing' as alternatives. But the majority agreed that separating out problem-finding from problem-solving was important.

Visualising was regarded as an important EHOM for all education sectors to cultivate, since it enabled an engineer to take an abstract idea and communicate a practical solution in a more concrete form:

To be able to take something abstract and then make it into a practical solution, you have to have that sort of visualisation to be able to do that.

Improving, or a relentless drive to improve products, was regarded as a core characteristic of an engineer. It was the result of constant tinkering and experimenting to find better solutions:

They [engineers] are never fully satisfied with a product or outcome and will try and modify and improve what they have designed or produced to make it better

However, this was not just for the sake of it, the underlying drive was to move society forward:

It's all about making things easier for people's lives...whether it's a product that you're making simpler to use, or making something quicker to use… its improving people's lives.

Creative problem-solving provoked strong reactions. There were those who thought that it was the most important EHOM:

This was predominantly the perspective expressed by those engaged in primary education, while those involved in post-compulsory engineering education expressed doubts, not about the importance of problem solving itself as an EHoM, but about preceding it with the adjective 'creative'. These respondents were in no doubt about the importance of creativity in engineering, because:

You often have to bring ideas from different disciplines and different divisions to solve the problem.

However, other thought that being creative might be in conflict with the requirements to consider previous solutions to problems and to adhere to recognised standards:

It is common in engineering to use concepts that are not original. Engineers would not normally think that they were being creative unless at least one of the options involved a new concept. Therefore the qualification of problem solving by the adjective creative excludes a lot of engineering work.

Adapting is an EHoM about which respondents had mixed views. Primary level educators thought that it was too sophisticated a concept for entry level engineers and could only be cultivated after they had some experience to draw on to make judgements. However, experienced engineers and those within higher education thought that it was an important EHoM:

[Adapting] is very important; a lot of engineering is doing the same things only slightly differently.

Several respondents suggested that it was unlikely that all our EHoM would be found in one engineer and stressed the overall importance of the team in successful engineering projects. Nevertheless, they argued that engineers should be sufficiently self-aware to know when it was appropriate to draw on the skills of others in the team: I think good engineers, certainly in a team, can do that. They can do what they have to do but they can also sort of observe themselves doing it and ask, "Am I using the appropriate skills at the appropriate points in all of this?

Engineers, as MacLeod puts it, rarely operate in one mode only, but are able to move between 'two modes of thinking' and as a consequence of these discussions we realised that much of the engineer's world is necessarily about holding a series of tensions in balance, for example, between using creativity to invent new ways of doing things and using logic to make things work:

Having found agreement on our six EHoM, we chose to represent our model in Fig.2 as series of concentric circles because it allowed us to: a) articulate at the core of the model the driving force of engineering – 'making stuff'; b) distinguish between two sets of habits of mind important to engineers, placing the more specific EHoM closer to the core, but recognising the relevance of a broader set of learning habits.

We recognise that the term 'making' refers principally to traditional engineering disciplines and also that engineers engage in all sorts of activity which may not involve making things [15]. However, even engineers such as chemical or software engineers who do not 'make' physical products as such, are involved in the sub-elements of making such as designing and implementing. It is this extended definition of 'making' to which we attach central importance.

UNIT-II

Ontology:

Ontology is the branch of philosophy that studies concepts such as existence, being, becoming, and reality. It includes the questions of how entities are grouped into basic categories and which of these entities exist on the most fundamental level. Ontology is sometimes referred to as the *science of being* and belongs to the major branch of philosophy known as metaphysics.

Reference Ontology and Application Ontology

Reference Ontologies

There appear to be three central characteristics of reference ontologies (ROs). We examine these in turn. Theoretical Focus on representation The first characteristic of ROs is their theoretical focus on representation. ROs are constructed without any particular concerns for computational efficiency. Consequently, ROs avail themselves of (at least) the language of full first-order logic. Specifically, ROs avail themselves of:

- Arbitrary n-place predicates;
- Full classical negation;
- Unbounded, arbitrarily nested quantifiers.

The focus of ROs on representation is most clearly indicated in their generally unapologetic use of full first-order languages. The three features above are particularly noteworthy, as unrestricted use of any of them can render complete deductive procedures intractable, even undecidable. Philosophical inclination toward realism The second feature of ROs is that their inclination toward philosophical realism.

There are generally two elements of this realism:

- Metaphysical realism;
- Epistemological realism.

According to metaphysical realism, the World (Reality, What There Is) exists objectively in itself, independent of any mind. According to epistemological realism, the World is knowable by us. Thus, the philosophical standpoint underlying most ROs is that the World and its properties are there to be discovered. This implies, in turn, that the World, being objective and knowable, puts constraints on what we can say about it. Thus, in our ontologies can get it wrong. An RO is right just insofar as it accurately reflects, as far as it goes, the way the World is. This leads to our third feature of ROs. Methodological emphasis on Truth Because our ROs can be wrong, there is in the construction of an RO a good reason to place a strong methodological emphasis on Truth.

This has two practical implications:

• The central function of an ontology is to represent the World accurately and comprehensively; hence:

• The quality of an ontology a function of its accuracy and comprehensiveness.

ROs are all about getting the world — or some important piece of it — right.

An ontology of time purports to describe its actual nature, to proffer the sober metaphysical truth on such matters as whether time is discrete, continuous, some combination of the two; whether there are timepoints or intervals, or both, and so on. Consequently, the quality of an ontology is judged along two dimensions: its accuracy — i.e.,

whether what it purports to be the case is in fact the case — and its comprehensiveness — i.e., whether it takes in a sufficiently broad spectrum of facts as to be significant.

Application Ontologies

Corresponding to our three features of reference ontologies are three salient features of application ontologies (AOs).

Theoretical Focus on Reasoning

Unlike ROs, AOs are typically designed with some sort of computational application — and hence its attendant expressive limitations — in mind. Consequently, AOs are usually expressed in the language of some computationally tractable sub logic of full firstorder logic (see, e.g., [6]). Such languages typically support:

• Reasoning about classes and "slots" through the use of unary and (limited) binary predicates;

• Conjunction and disjunction, but not negation;

Philosophical inclination toward pragmatism/ instrumentalism/constructivism

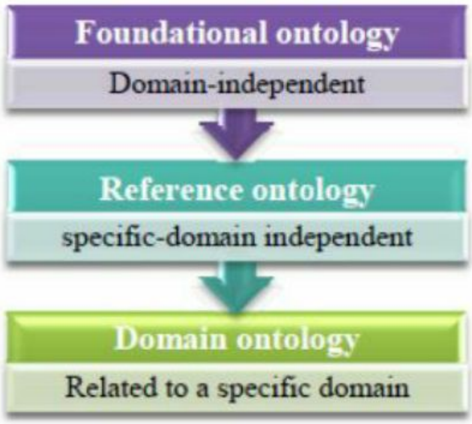
Unlike the strong realism underlying ROs, for AOs, take a far more pragmatic view of the world, both metaphysically and epistemologically. Specifically, the metaphysical presumption underlying a typical AO is the falsity, or at least the irrelevance, of metaphysical realism. The objects and structures we encounter in the world — those parts of it that matter to ontology, anyway — are social constructs, products of the evolving interaction between conscious, intelligent human agents and, at best, a substrate of unknowable.

The corresponding epistemological presumption is that, even if metaphysical realism is true and there is an ultimate metaphysical reality to the world, that underlying reality probably unknowable anyway. Hence, what we can be said to know is simply what works.

Methodological emphasis on fidelity

Methodologically, the central emphasis of an AO must be on fidelity, i.e., to be a faithful expression of the concepts/intuitions of relevant domain experts or sources. All that matters to an AO is how relevant domain experts conceptualize a given domain. The question of any sort correspondence between that conception and an objective external world is idle philosophical speculation with no bearing on the quality of the ontology, which is determined entirely by the extent of its fidelity.

On the face of it, these two approaches two ontology are profoundly different. However, the starkest differences are philosophical; indeed, those differences are probably irreconcilable. However, important as those differences might be conceptually, at the end of the day what we are engaged in is knowledge engineering. And as engineers, I suggest the following tendentious (not to say controversial) thesis: the only components of the two approaches that ultimately matter are the theoretical and methodological. These, I will argue are compatible, indeed complementary. wide-scope universal quantifiers only)



Ontological Layers

Reference ontology with regard to application ontology

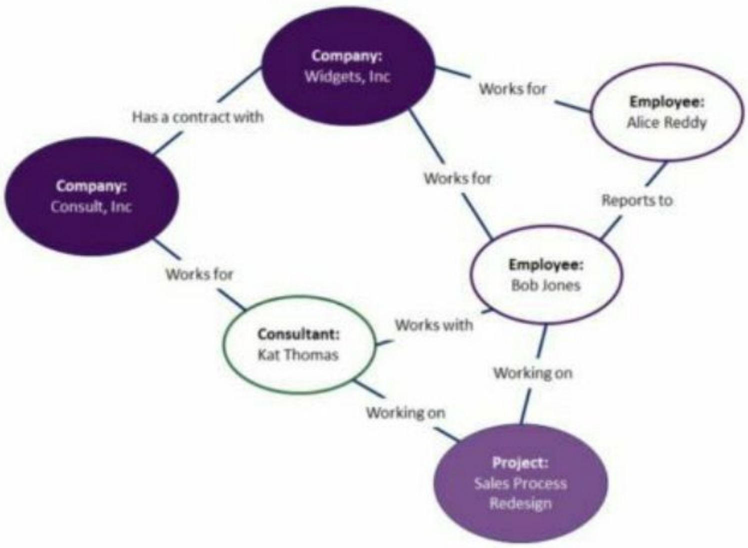
Application ontologies contain all the definitions that are needed to model the knowledge required for a particular application. They are not reusable themselves.

"Application ontologies describe concepts depending both on a particular domain and task, which are often specializations of both the related ontologies. These concepts often correspond to roles played by domain entities while performing a certain activity, like replaceable unit or spare component ".

Reference ontology versus Application ontology

Reference Ontology	**Application Ontology**
theoretical Focus on representing	theoretical Focus on representing
establishes consensus about meaning of	offers terminological services for semantic

terms	access, checking constraints between terms
maximal coverage	provides a minimal terminological structure
Fits the needs of a large community	fits the needs of a specific community
Fits the needs of a large community	lightweight ontologies
Can't be derived from application ontology	can be derived from Reference ontology
broad and deep	broad and deep
designed according to strict ontological principles	designed according to the viewpoint of an end-user in a particular domain



Ontology example

What Is the Product Life Cycle?

PLC is an assumption that every product goes through that involves the same pattern of introduction into the market, growth, maturity, and decline. As the product spends more time in the market and it makes its way through the cycle, its sales increase. Each product's PLC is different in the length of scope and duration, and each product is at risk of not making it out of the introduction phase. However, the company strategy should remain consistent throughout each of the phases.

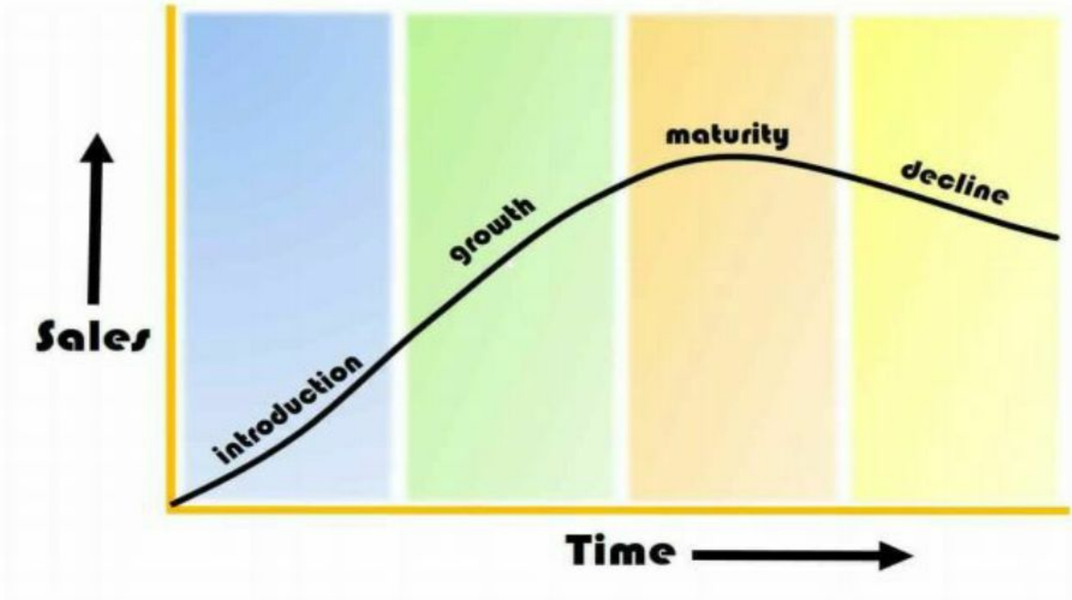
The PLC, in brief, is as follows:

Stage 1: Product Development: The new product is introduced; this is when all of the research and development happens.

Stage 2: Product Growth: The product is more than an idea or a prototype. At this stage, the product is manufactured, marketed, and released. Distribution increases, demand increases, and competition also increases.

Stage 3: Product Maturity: During this stage, the product is widely available, and there are many competitors in the marketplace. You market the product to different segments, but more spending on advertising will have no impact on its demand.

Stage 4: Product Decline: The product is losing market share, or becoming obsolete. It is well past its point of highest demand, and the demand decreases.

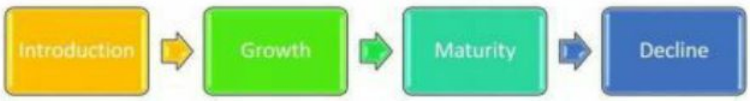


Additionally, the product life cycle affects the average selling price (ASP). The ASP is how much you generally sell your products or services for. When a product has many competitors or it is in the decline stage of its PLC, the ASP will be lower.

Product image also drives the ASP. Products with an image of exclusivity have a higher ASP. For example, Louis Vuitton luggage is considered a luxury brand of products that are made by hand and use the finest materials. There is a limited assortment of products, a long wait time to procure one, and a higher than average price point. The company has even sped up their manufacturing process, but the price point still reflects the exclusivity and time to market of a custom bag. In fact, Louis Vuitton increased its prices in 2013 to attract more high-end consumers because they experienced a decline. This approach is an interesting twist on the PLC since normally the prices would drop with the waning in demand.

Closed-Loop Manufacturing Cycle

So far, we have been discussing the typical PLC. It is linear and at each stage has material, labor, and resource inputs. It also has waste outputs that can negatively affect the environment. Researchers assert that the introduction stage where design takes place determines between 70 percent and 90 percent of the life cycle costs. At this stage, manufacturers can also remove excess waste and continue to develop sustainable manufacturing practices. These practices should include products being reused, recycled, and remanufactured. With this, you are developing a closed-loop manufacturing cycle. Instead of a linear PLC, this represents a circular PLC.



A closed-loop cycle is a natural extension of PLM, and creates a truly full life cycle that takes your obsolete or used products back into raw materials, not just assigning them to waste. Although many of these closed-loop products are down cycled (converted into lesser-quality materials), the products are still recycled and reused repeatedly.

An example of this is Dell's take-back program, which takes the computers that it manufacturers and turns a majority of them into new computers. Other companies separate out product components and sell them to their partners on the commodities market, as raw materials, who then make them into new products. The benefits of a closed-loop system include:

- Better for the environment
- Does not affect performance or price
- Fewer carbon emissions in manufacturing
- As programs scale, they become cheaper and more effective

Commodities:

Commodities are an important aspect of most American's daily life. A commodity is a basic good used in commerce that is interchangeable with other goods of the same type. Traditional examples of commodities include grains, gold, beef, oil, and natural gas.

For investors, commodities can be an important way to diversify their portfolios beyond traditional securities. Because the prices of commodities tend to move in opposition to stocks, some investors also rely on commodities during periods of market volatility.

In the past, commodities trading required significant amounts of time, money, and expertise, and was primarily limited to professional traders. Today, there are more options for participating in the commodity markets.

- Commodities that are traded are typically sorted into four categories broad categories: metal, energy, livestock and meat, and agricultural.
- For investors, commodities can be an important way to diversify their portfolios beyond traditional securities.
- In the most basic sense, commodities are known to be risky investment propositions because their market (supply and demand) is impacted by uncertainties that are difficult or impossible to predict, such as unusual weather patterns, epidemics, and disasters both natural and human-made.
- There are a number of ways to invest in commodities, such as futures contracts, options, and exchange traded funds (ETFs).

UNIT-III

Epistemology of Engineering

Science, Engineering, and Technology are often confused with each other. All three are closely related but mean different things. In this post, we have tried to bring out the differences between science, engineering, and technology. Let's start with a quote that brings out the difference between Science & Engineering:

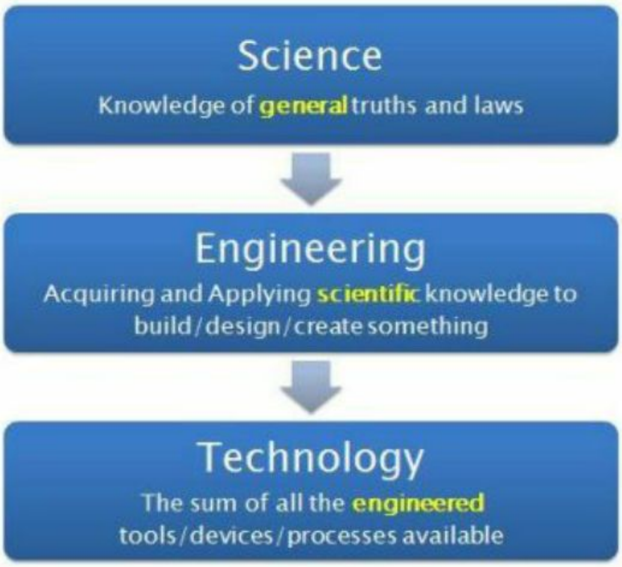
"Scientists study the world as it is; engineers create the world that has never been."

—Theodore von Kármán

As per the quote, we can observe that science is a study of the natural world while Engineering is creating new things based on that study. However, I would like to modify the quote in order to bring out a comparison between science, engineering and technology:

"Science is the study of the natural world as it is; engineering is creating new tools, devices, and processes based on ***scientific*** knowledge; technology is the sum total of all the ***engineered*** tools, devices and processes available."

In the above quote, we can clearly see the difference as well as the interconnection between science, engineering, and technology. This can be explained using the image that follows:



Now that we know the basic definitions and the overall comparison between the three, let's move to a set of alternate differences between them. The differences below may seem redundant, and that's because they are. They are all different ways of saying the same thing. Choose whichever appeals you the most:

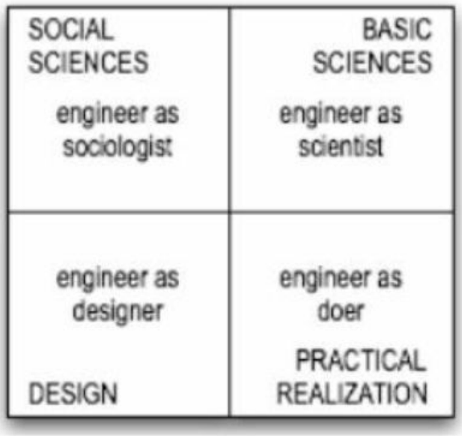
1. Science is knowledge of the natural world put together, Engineering is creation based on the scientific knowledge put together, and Technology is the set of engineered creations put together.

2. Science comes from observation of the world, Engineering comes from aquiring and applying knowledge, and Technology comes from repeated application and approval of the engineered tools.

3. Science is about creating meaning of natural phenomenon, Engineering is about creating new devices, tools and processes, and Technology is about creating a collection of engineered and tested tools for the mankind.

Four Dimensions of Engineering:

In the discussion of engineering knowledge it is helpful to think of engineering as comprising four major dimensions (Fig. 1): the dimensions of the basic sciences, of the social sciences, of design, and of practical accomplishment. This lets us think of the engineer as a professional who combines, in variable proportions, the qualities of a scientist, a sociologist, a designer, and a doer.

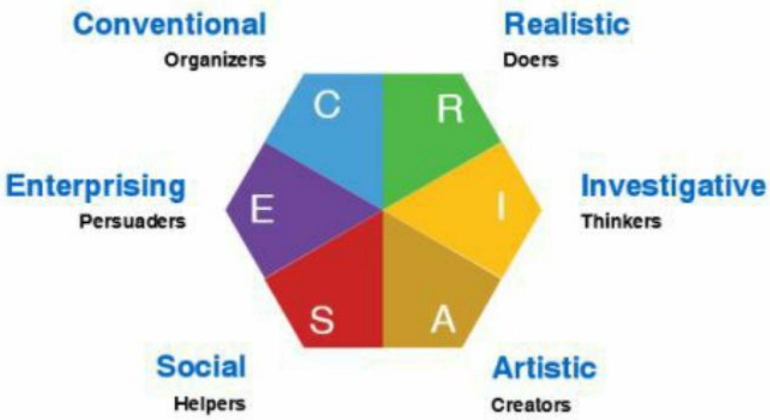


The dimension inspired by the basic sciences views engineering as the application of the natural and exact sciences, stressing the values of logics and rigour, and seeing knowledge as produced through analysis and experimentation. Research is the preferred modus operandi of this dimension, where the discovery of first principles is seen as the activity leading to higher recognition. The social dimension of engineering sees engineers not just as technologists, but also as social experts, in their ability to recognize the eminently social nature of the world they act upon and the social complexity of the teams they belong to. The creation of social and economic value and the belief in the satisfaction of end users emerge as central values in this dimension of engineering.

The design dimension sees engineering as the art of design. It values systems thinking much more than the analytical thinking that characterizes traditional science. Its practice is founded on holistic, contextual, and integrated visions of the world, rather than on partial visions. Typical values of this dimension include exploring alternatives and compromising. In this dimension, which resorts frequently to non-scientific forms of thinking, the key decisions are often based on incomplete knowledge and intuition, as well as on personal and collective experiences. The fourth mode views engineering as the art of getting things done, valuing the ability to change the world and overcoming complexity with flexibility and perseverance. It corresponds to the art of the homo faber, in its purest expression, and to the ability to tuck up one's sleeves and get down to the nitty-gritty. In this dimension, the completed job, which stands before the world, leads to higher recognition.

RAISEC Model:

In the 1950s, John Holland theorized that personality and work environment are measurable, and that the two should be matched in order to find a satisfying career. Holland's theory describes six basic personality types (**RIASEC**, described below). One type is typically dominant; an individual's top three types -- in order -- make up that person's Holland Code. The goal is to match an individual's code, or personality type, with his or her career.



Realistic - R (Doers)
Like to work with their hands and focus on things in the physical world & use physical skills. Like to repair and work with tools, machines, or animals; outdoor work is often preferred. Prefer problems that are concrete rather than abstract; want practical solutions that can be acted out. Characteristics include stable, assertive, physical strength, practical.
Holland typology: realistic practical frank nature lover curious concrete selfcontrolled ambitious persistent athletic mechanical thrifty stable reserved independent systematic.

Investigative - I (Thinkers)

Tend to focus on ideas. Like to collect and analyze data and information of all kinds. Curious and tend to be creative and original. Task oriented and motivated by analyzing and researching. Tend to prefer loosely structured situations with minimal rules or regulations. Prefer to think through rather than act out problems. Characteristics include reserved, independent, analytical, logical.
Holland typology: investigative inquisitive scientific precise cautious self-confident reserved independent analytical observant scholarly curious introspective broad-minded logical.

Artistic - A (Creators)

Creative and tend to focus on self-expression through all kinds of mediums: materials, music and words, as well as systems and programs. Able to see possibilities in various settings and are not afraid to experiment with their ideas. Like variety and tend to feel cramped in structured situations. Deal with problems in intuitive, expressive, and independent ways. Tend to be adverse to rules. Characteristics include intuitive, creative, expressive, unconventional.
Holland typology: artistic creative imaginative unconventional independent original impulsive courageous complicated nonconforming intuitive innovative emotional expressive introspective sensitive open idealistic.

Social - S (Helpers)

Concerned with people and their welfare. Tend to have well developed communications skills and like to help, encourage, counsel, guide, train, or facilitate others. Enjoy working with groups or individuals, using empathy and an ability to identify and solve problems. Value cooperation and consensus. Deal with problems through feelings. Flexible approach to problems. Characteristics include humanistic, verbal, interpersonal, responsible.
Holland typology: social friendly idealistic outgoing cooperative responsible kind persuasive patient helpful insightful understanding generous forgiving empathetic.

Enterprising - E (Persuaders)

Work with and through people, providing leadership and delegating responsibilities for organizational and/or financial gain. Goal-oriented and want to see results. Tend to function with a high degree of energy. Prefer business settings, and often want social events to have a purpose beyond socializing. Attack problems with leadership skills. Decision-Maker. Characteristics include persuasive, confident, demonstrate leadership, interest in power/status.
Holland typology: enterprising self-confident sociable enthusiastic adventurous impulsive inquisitive talkative spontaneous assertive persuasive energetic popular ambitious optimistic extroverted.

Conventional - C (Organizers)

- Like to pay a lot of attention to detail and organization, and prefer to work with data, particularly in the numerical, statistical, and record-keeping realm. Have a high sense of responsibility, follow the rules, and want to know precisely what is expected. Prefer clearly defined, practical problems and to solve problems by applying rules. Oriented to carrying out tasks initiated by others. Characteristics include conscientious, efficient, concern for rules and regulation, orderly.

Holland typology: conventional well-organized accurate numerically-inclined methodical efficient orderly thrifty structured ambitious persistent conscientious conforming practical systematic polite obedient.

Epistemology of Engineering Design

Design as activity is related to the conceptualization (pre-execution) stages of making new products. Design as activity is usually further organized under "art versus technique" or "form versus function". Fine art, industrial design (applied art), architecture and engineering are typical examples of design as activity.

Design as planning is related to the systematic mental processes prior to actions and conceptualization (pre-execution) stages for planning composing and decision making. While design as activity is more related to professional endeavors like art or engineering, design as planning is more affiliated with management of a wide range of fields from business to military and from hospitals to academy.

Design as epistemology is related to the synthetic methodologies needed for the mental apprehension of appropriateness for change. Design epistemology is distinct from analytic methodologies, which is crucial to develop scientific initiatives.

Taking as a reference the proposed four-dimensional model and the epistemology of design briefly discussed in the previous section, the remainder of the talk analyses the epistemology of engineering in light of the four key questions of the philosophy of knowledge: the ontological, the epistemological, the methodological, and the axiological questions.

For the case of engineering, the ontological question inquires about what reality can engineering know, the epistemological question looks into what is engineering knowledge, the methodological question asks how can engineering knowledge be built, and the axiological question (which includes the ethical question), inquires about the worth and value of engineering knowledge. The talk answers these questions in the context of the proposed model.

It also stresses the key distinctive features of engineering knowledge that emerge from the strong presence of a design dimension. This includes the importance attached to abductive reasoning and the acceptance of courses of action that seize upon chance information, adopt capricious ideas, and provoke creative leaps that seem to go against traditional scientific rigour.

In this respect, Popper's concept of 'critical discussion' will be used to illustrate how the epistemology of engineering can derive final and verifiable rigour from such apparently unsystematic, imprecise, and even random, intermediate steps.

Rigour, Creativity and Change in Engineering

Engineers' drive for innovation can be significantly curtailed by the "bottom line" finances available. Obtaining parts for experimentation in practically zero time can require very resourceful effort because the rigid systems in place for parts procurement too often have been established primarily for production and "just-in-time" receipt. One partial solution is obtaining "samples," but these are sometimes unreliable parts—and a single failure can result in quick dismissal of a project by management. Rigorous design rules, such as parts derating, design reviews (Preliminary Design Reviews, Critical Design Reviews, and Final Design Reviews) and many "-ilities" are important. But with tight constraints on schedules and finances they often severely limit time for experimentation.

Suggestions:

• Make a list of solutions very early in the design process. This would certainly include the solution proposed, but might have variants that could be more or less innovative, and might save cost.

• Most design efforts involve team effort and the ability to compromise, combined with the resolve to do right. Sometimes you can get your wishes met by just 'floating" an idea and letting others scramble to take credit for it.

• Keep the design as simple as possible.

• Try to anticipate how the design will look when released to production. Will it survive the test of time going forward with minimal Engineering Change Orders and compromises?

• Will it fill a requirement that could be adapted to some future upgrade with minimal interface changes? Can we fill this space with something better in the future?

• Discuss your ideas with others in various disciplines outside of engineering to get their inputs: project management, QA, reliability, manufacturing, etc.

• Make the first meeting with the customer exciting by showing solutions considered and even making "mock-ups" of what the product might look like. Make sure the customer understands your interpretation of what they want. Sometimes there is wide difference between the written word and what they really need. Get changes in writing!

• Be practical about where parts can be obtained. Try to insure that sample parts are reasonably reliable and not counterfeit, or rejects.

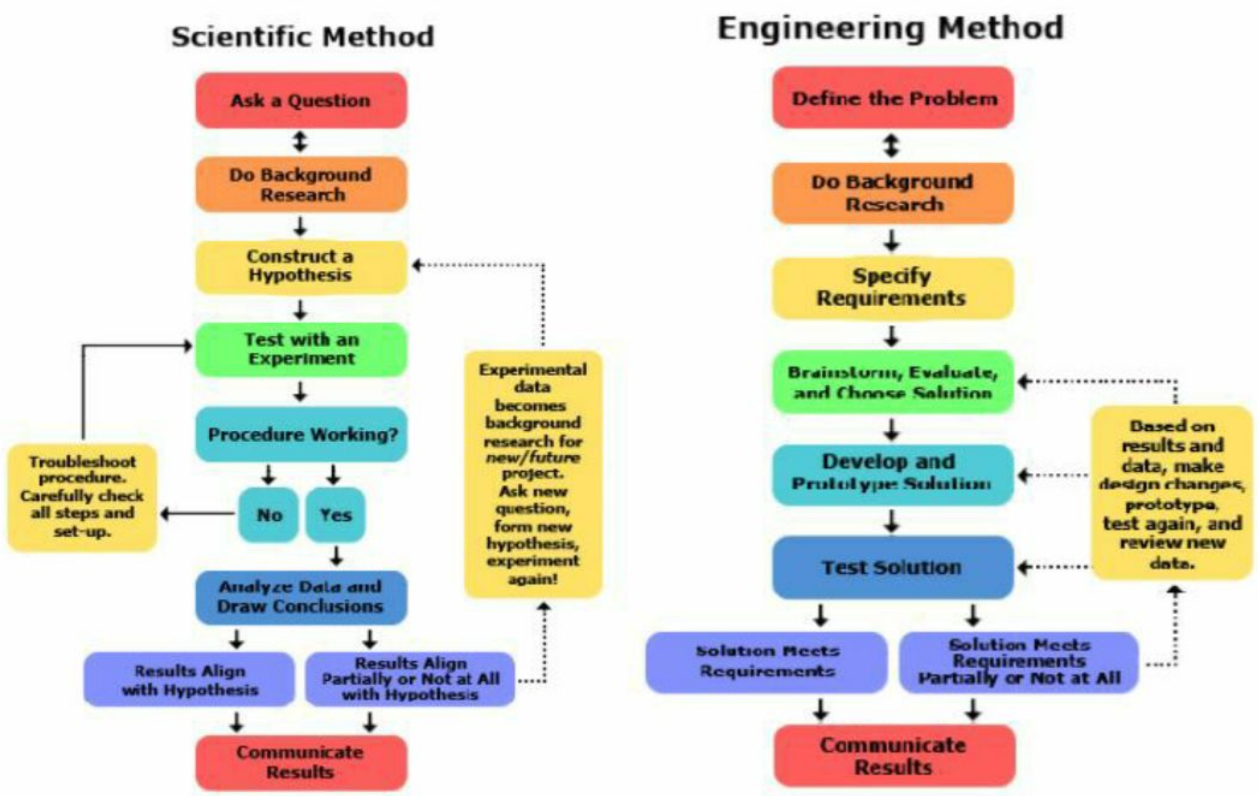
Finally: remember that not all projects will be overwhelmingly successful. Some are praiseworthy but flawed concepts while others may be inadequately funded. But while you cannot be responsible for everything that happens, never let distractions interfere with your next good idea.

UNIT IV

METHODOLOGY OF ENGINEERING

DIFFERENCE BETWEEN SCIENTIFIC METHOD AND ENGINEERING DESIGN

While scientists study how nature works and discover new knowledge about the universe, engineers create or construct new things, such as products, websites, environments, and experiences. Because engineers and scientists have different objectives, they follow different processes in their work. Scientists perform experiments using the scientific method; whereas engineers follow the creativity-based engineering design process. You can see the steps of each process in these flowcharts:



The Scientific Method	The Engineering Design Process
State your question	Define the problem
Do background research	Do background research
Formulate your hypothesis, identify variables	Specify requirements
Design experiment, establish procedure	Create alternative solutions, choose the best one and develop it

The Scientific Method	The Engineering Design Process
Test your hypothesis by doing an experiment	Build a prototype
Analyze your results and draw conclusions	Test and redesign as necessary
Communicate results	Communicate results

Why are there two processes?

Both scientists and engineers contribute to the world of human knowledge, but in different ways. Scientists use the scientific method to make testable explanations and predictions about the world. A scientist asks a question and develops an experiment, or set of experiments, to answer that question. Engineers use the engineering design process to create solutions to problems. An engineer identifies a specific need: **Who** need(s) **what** because **why**? And then, he or she creates a solution that meets the need.

Which process should I follow for my project?

Watch the video to see what it looks like to tackle the same topic using the scientific method versus the engineering design process.

In real life, the distinction between science and engineering is not always clear. Scientists often do some engineering work, and engineers frequently apply scientific principles, including the scientific method. Much of what we often call "computer science" is actually engineering—programmers creating new products. Your project may fall in the gray area between science and engineering, and that's OK. Many projects, even if related to engineering, can and should use the scientific method.

However, if the objective of your project is to invent a new product, computer program, experience, or environment, then it makes sense to follow the engineering design process.

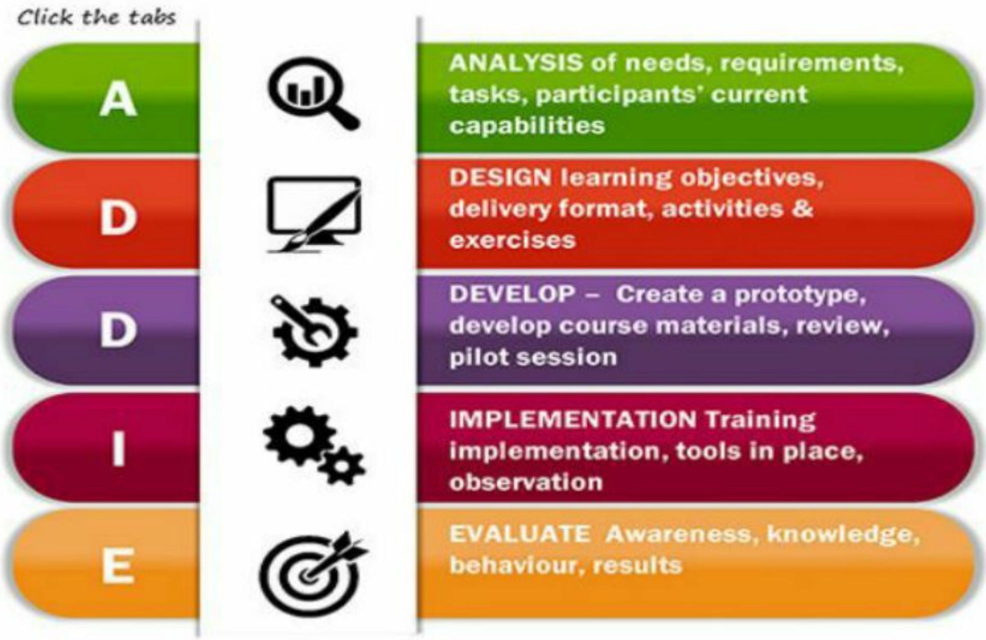
ADDIE MODEL:

The ADDIE model is the generic process traditionally used by instructional designers and training developers. The five phases—Analysis, Design, Development, Implementation, and Evaluation—represent a dynamic, flexible guideline for building effective training and performance support tools. While perhaps the most common design model, there are a number of weaknesses to the ADDIE model which have led to a number of spin-offs or variations.
It is an Instructional Systems Design (ISD) model. Most of the current instructional design models are spin-offs or variations of the ADDIE model; other models include the Dick & Carey and Kemp ISD models. One commonly accepted improvement to this model is the use of rapid prototyping. This is the idea of receiving continual or formative feedback while instructional materials are being created. This model attempts to save time and money by catching problems while they are still easy to fix.

Instructional theories also play an important role in the design of instructional materials. Theories such as behaviorism, constructivism, social learning and cognitivism help shape and define the outcome of instructional materials.

In the ADDIE model, each step has an outcome that feeds into the subsequent step.

Analysis > Design > Development > Implementation > Evaluation



Analysis Phase

In the analysis phase, instructional problem is clarified, the instructional goals and objectives are established and the learning environment and learner's existing knowledge and skills are identified. Below are some of the questions that are addressed during the analysis phase:

* Who is the audience and their characteristics?
* Identify the new behavioral outcome?
* What types of learning constraints exist?
* What are the delivery options?
* What are the online pedagogical considerations?
* What is the timeline for project completion?

Design Phase

The design phase deals with learning objectives, assessment instruments, exercises, content, subject matter analysis, lesson planning and media selection. The design phase should be systematic and specific. Systematic means a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the project's goals. Specific means each element of the instructional design plan needs to be executed with attention to details.

These are steps used for the design phase:

* Documentation of the project's instructional, visual and technical design strategy
* Apply instructional strategies according to the intended behavioral outcomes by domain

(cognitive, affective, psychomotor).
* Create storyboards
* Design the user interface and user experience
* Prototype creation
* Apply visual design (graphic design)

Development Phase

The development phase is where the developers create and assemble the content assets that were created in the design phase. Programmers work to develop and/or integrate technologies. Testers perform debugging procedures. The project is reviewed and revised according to any feedback given.

Implementation Phase

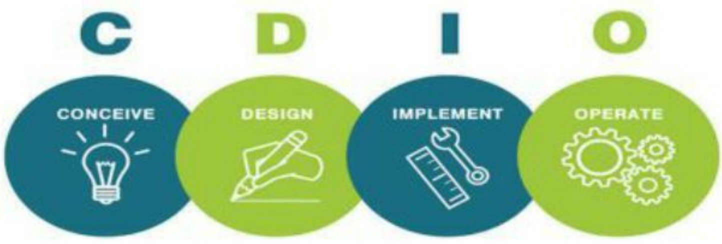
During the implementation phase, a procedure for training the facilitators and the learners is developed. The facilitators' training should cover the course curriculum, learning outcomes, method of delivery, and testing procedures. Preparation of the learners include training them on new tools (software or hardware), student registration.

This is also the phase where the project manager ensures that the books, hands on equipment, tools, CD-ROMs and software are in place, and that the learning application or Web site is functional.

Evaluation Phase

The evaluation phase consists of two parts: formative and summative. Formative evaluation is present in each stage of the ADDIE process. Summative evaluation consists of tests designed for domain specific criterion-related referenced items and providing opportunities for feedback from the users.

CDIO ENGINEERS IN INDUSTRY



Conceive:
- Defining Customer needs
- Considering technology
- Enterprise Strategy and regulations
- Developing Concepts, techniques and
- Business Plan

Design:

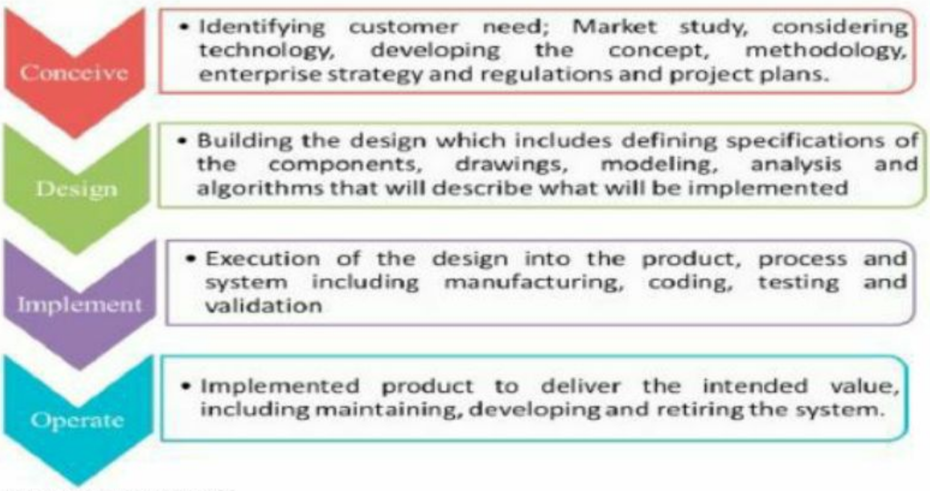
- Creating the design
- The plans, drawings and algorithms that describe what will be implemented

Implement:

- The transformation of design into the product, including manufacturing, coding , testing and validation

Operate:

- Using the implemented product to deliver the intended values, including maintaining, evolving and retiring the system



ENGINEERING DESIGN PROCESS

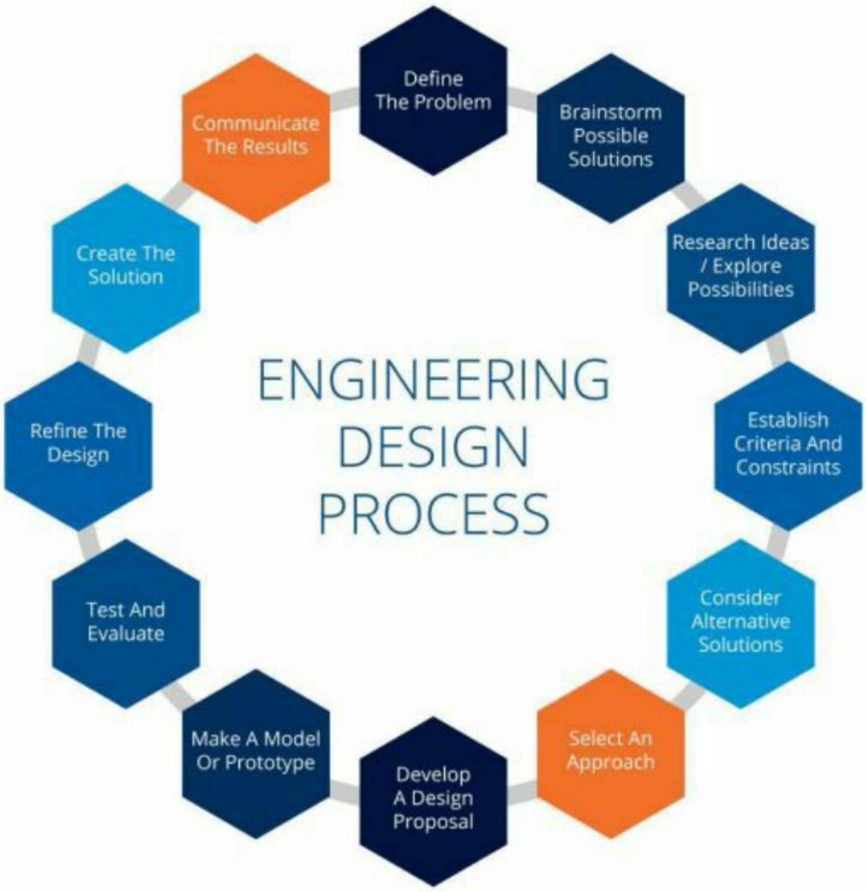
The engineering design process is a series of steps that engineers follow to find a solution to a problem. The steps include problem solving processes such as, for example, determining your objectives and constraints, prototyping, testing and evaluation.

The process is important to the work conducted by TWI and is something that we can offer assistance with.

While the design process is iterative it follows a predetermined set of steps, some of these may need to be repeated before moving to the next one. This will vary depending on the project itself, but allows lessons to be learnt from failures and improvements to be made.

The process allows for applied science, mathematics and engineering sciences to be used to achieve a high level of optimisation to meet the requirements of an objective. The steps include problem solving processes such as, for example, determining your objectives and constraints, prototyping, testing and evaluation.

The steps of the engineering process are not always followed in sequence, but it is common for engineers to define the problem and brainstorm ideas before creating a prototype test that is then modified and improved until the solution meets the needs of the engineers project. This is called iteration and is a common method of working.



1. Define The Problem

What is the problem that needs to be solved? Who is the design product for, and why is it important to find a solution? What are the limitations and requirements? Engineers need to ask these types of critical questions regardless of what is being created.

2. Brainstorm Possible Solutions

Good designers brainstorm possible solutions before opting to start a design, building a list of as many solutions as possible. It is best to avoid judging the designs and instead just let the ideas flow.

3. Research Ideas / Explore Possibilities for your Engineering Design Project

Use the experience of others to explore possibilities. By researching past projects you can avoid the problems faced by others. You should speak to people from various backgrounds, including users or customers. You may find some solutions that you had not considered.

4. Establish Criteria and Constraints

Having listed potential solutions and determined the needs of the project alongside your research, the next step is to establish any factors that may constrain your work. This can be done by revisiting the requirements and bringing together your findings and ideas from previous steps.

5. Consider Alternative Solutions

You may wish to consider further solutions to compare the potential outcomes and find the best approach. This will involve repeating some of the earlier steps for each viable idea.

6. Select An Approach

Once you have assessed your various options you can determine which approach best meets your requirements. Reject those that don't meet your requirements.

7. Develop A Design Proposal

Having chosen your approach, the next step is to refine and improve the solution to create a design proposal. This stage can be ongoing through the length of your project and even after a product has been delivered to customers.

8. Make A Model Or Prototype

Use your design proposal to make a prototype that will allow you to test how the final product will perform. Prototypes are often made from different materials than the final version and are generally finished to a lesser standard.

9. Test And Evaluate

Each prototype will need testing, re-evaluation and improvement. Testing and evaluation allows you to see where any improvements are needed.

10. Refine The Design

Once testing has been completed, the design can be revised and improved. This step can be repeated several times as more prototypes are created and evaluated.

11. Create The Solution

After your refinements have been completed and fully tested, you can decide upon and create your finished solution. This may take the form of a polished prototype to demonstrate to customers.

12. Communicate The Results

The final stage is to communicate your results. This can be in the form of a report, presentation, display board, or a combination of methods. Thorough documentation allows your finished product to be manufactured to the required quality standards.

OPERATIONAL FACTORS IN SYSTEM DESIGN

One of the most intriguing aspects of software architecture is trying to bring structure to areas that can't be structured easily. Whenever an architect designs a system, service, or feature, they are formulating a typical yet comprehensive solution to a unique problem.

The key concepts outlined here are valuable in designing an efficient, scalable, accessible, secure, and cost-friendly architecture.

Integrity and Consistency

The integrity of the data the system operates on is of the highest consideration when designing a reliable and fault-tolerant architecture. The system should be designed to provide redundant backups that maintain data integrity and all-around consistency.

Performance and Scalability

Modern web applications are built to scale, and an elastic architecture that scales as the traffic grows ensures business needs are not impacted by a large customer base. The architecture should encompass scalability approaches in the design, code, and infrastructure phases.

Deployment Strategy

A deployment process, whether in the cloud or on-premises, should be an integral part of the architecture design. Deployment methodologies such as continuous integration and continuous deployment (CI/CD) should ideally be a fabric of this design to streamline the deployments of builds.

Security

In today's world of ubiquitous and pervasive computing, a user's sensitive information and overall data security is of paramount importance. An architectural design should insist on incorporating security procedures as a pattern and enforce strong security practices via configuration or convention.

User Experience and Inclusivity

Pertinent to user-facing systems, the end-user experience is paramount in architecture design. Experience architecture (XA) is the process of articulating the user's journey from one subsystem to another within an application, and is vital in providing the user with helpful controls, hints, and other methods to navigate. The system architecture should also include accessibility design as a part of the user experience, so they can navigate an application thoroughly regardless of physical or cognitive differences.

Recovery and Planning

Data recovery (DR) and business continuity planning (BCP) should be vital parts of an architectural design that ensures business needs are not largely affected when an unforeseen event occurs.

Unit Testing

A resilient architecture should incorporate unit testing as an essential component of its design. A code coverage report generated on each build provides opportunities for code reviews within the team where any inconsistencies can be discovered quickly. Automation should be explored as an integral element of the architecture wherever possible, and not as an afterthought.

Application Performance Monitoring

Even the best engineered systems fail. And when they do, the architecture should be robust enough to offer the end-users and the development teams support information with what went wrong, when, and why. Application performance monitors (APMs) are particularly useful in providing detailed insights on application issues.

Overall, a system architect's role and performance is defined by the concept, design, development, and maintenance of the application they architect.

UNIT V

AXIOLOGY OF ENGINEERING

ENGINEERING AND SOCIETY

Are you aware of the extent of the impact engineering has made on our society as a whole? In fact, engineers have completely changed the world we live in, from modern homes, bridges, space travel, cars and the latest mobile technology. Innovative ideas are at the heart of what engineers do, and they use their knowledge to create new and exciting prospects and solve any problems that may arise.

Health

The health industry has hugely benefitted from engineering. Advances in medical technology is solely down to engineers, and without it doctors would not be able to treat patients the way they do today; with fantastic success rates. Engineering has essentially allowed us to understand the medical issues in today's society.

Technology

Engineers are the reason for the phenomenal growth in technology of every generation. Just think about what the technological advances that are in our everyday lives; not only can we access the world with our fingertips, engineers have also allowed us to build satellites and machines that help us to understand the world we live and shape our lives on a daily basis.

Communication

Whilst on the subject of technology, the way we communicate has also vastly improved due to engineering. We can now get in touch with people at any time of the day in any part of the world. This has greatly improved the way we do business and how we talk to our friends, family and strangers on a daily basis.

Development

Steam engines, jet engines and aeroplanes are all down to hard work from engineers, and it has allowed businesses to work smarter and faster than ever before. Improvements to travel have changed the way humans connect with one another, opening trades for business and allowing us to literally travel to the other side of the planet in a mere 24 hours.

Space

Visiting Space may have been a mere dream in the past, but not anymore. The International Space Station is the largest and most complex science undertaking ever. It allows scientists, analysts and engineers from all over the planet to come together and conduct research that cannot be done elsewhere, finding answers to queries that have been unquestioned for years.

There are no aspects of the world we live in today that isn't affected by the work of engineers. The great thing is that engineering is continuing to affect society in a great and beneficial way.

ENGINEERS CODE OF ETHICS

Preamble

Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.

I. Fundamental Canons

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. Rules of Practice

1. Engineers shall hold paramount the safety, health, and welfare of the public.
    a. If engineers' judgment is overruled under circumstances that endanger life or property, they shall notify their employer or client and such other authority as may be appropriate.
    b. Engineers shall approve only those engineering documents that are in conformity with applicable standards.
    c. Engineers shall not reveal facts, data, or information without the prior consent of the client or employer except as authorized or required by law or this Code.
    d. Engineers shall not permit the use of their name or associate in business ventures with any person or firm that they believe is engaged in fraudulent or dishonest enterprise.
    e. Engineers shall not aid or abet the unlawful practice of engineering by a person or firm.
    f. Engineers having knowledge of any alleged violation of this Code shall report thereon to appropriate professional bodies and, when relevant, also to public authorities, and cooperate with the proper authorities in furnishing such information or assistance as may be required.

Engineers shall perform services only in the areas of their competence.

. Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved.

a. Engineers shall not affix their signatures to any plans or documents dealing with subject matter in which they lack competence, nor to any plan or document not prepared under their direction and control.

b. Engineers may accept assignments and assume responsibility for coordination of an entire project and sign and seal the engineering documents for the entire project, provided that each technical segment is signed and sealed only by the qualified engineers who prepared the segment.

Engineers shall issue public statements only in an objective and truthful manner.

. Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony, which should bear the date indicating when it was current.

a. Engineers may express publicly technical opinions that are founded upon knowledge of the facts and competence in the subject matter.

b. Engineers shall issue no statements, criticisms, or arguments on technical matters that are inspired or paid for by interested parties, unless they have prefaced their comments by explicitly identifying the interested parties on whose behalf they are speaking, and by revealing the existence of any interest the engineers may have in the matters.

Engineers shall act for each employer or client as faithful agents or trustees.

. Engineers shall disclose all known or potential conflicts of interest that could influence or appear to influence their judgment or the quality of their services.

a. Engineers shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.

b. Engineers shall not solicit or accept financial or other valuable consideration, directly or indirectly, from outside agents in connection with the work for which they are responsible.

c. Engineers in public service as members, advisors, or employees of a governmental or quasi-governmental body or department shall not participate in decisions with respect to services solicited or provided by them or their organizations in private or public engineering practice.

d. Engineers shall not solicit or accept a contract from a governmental body on which a principal or officer of their organization serves as a member.

Engineers shall avoid deceptive acts.

. Engineers shall not falsify their qualifications or permit misrepresentation of their or their associates' qualifications. They shall not misrepresent or exaggerate their responsibility in or for the subject matter of prior assignments. Brochures or other presentations incident to the solicitation of employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint venturers, or past accomplishments.

a. Engineers shall not offer, give, solicit, or receive, either directly or indirectly, any contribution to influence the award of a contract by public authority, or which may be reasonably construed by the public as having the effect or intent of influencing the awarding of a contract. They shall not offer any gift or other valuable consideration in order to secure work. They shall not pay a commission, percentage, or brokerage fee in order to secure work, except to a bona fide employee or bona fide established commercial or marketing agencies retained by them.

SUSTAINABILITY AND DIVERSITY :

Sustainability is:

"Development which meets the needs of current generations without compromising the ability of future generations to meet their own needs."

In simple words: how we live today impacts the ability of our future generations to lead a good life. Our planet has many resources, some are finite while others can be replenished; however, in today's scenario, even our replenishable resources are depleting due to over consumption. Through sustainable practice we understand how to use our resources responsibly with a view to long-term consequences.

With this understanding, we could say that sustainability is about our resources and is mostly concerned with environmental issues. Therefore, often sustainability is interchangeably used for environmental sustainability. However, it is much more than that and can be explained by the **concept of 3Es**.

3Es stand for **environmental, economic and ethical** (also referred to as equity or social). Only a balance between all these three aspects could lead to sustainable development.

E #1: Environment

This is the **most discussed aspect of sustainability**. Companies are making huge efforts to reduce their carbon footprint, waste, water usage, non-environmentally friendly packaging and the overall negative impact on the environment. In order to achieve reduced carbon footprint, companies must consider their global operations, supply chain, factory or office locations, communities they operate in, and so on. To succeed in this task, they must effectively communicate and collaborate with individuals from diverse backgrounds and expertise.

A diverse, equitable, and inclusive workplace improves the environmental impact of a company. Here are **some ways of how it can be achieved**:

1. ***Equity and inclusion helps create equitable and inclusive processes:*** To successfully optimize the organization, it is important to include all the stakeholders and create processes that will enable each individual with the support they require. Without processes that include everyone and support individual needs, the company will miss out on a considerable segment of stakeholders participation.

2. ***Inclusive leaders possess higher cultural intelligence and skills to manage diversity:*** To improve the environmental footprint of a company, leaders need to effectively communicate with many individuals from different backgrounds, externally as well as internally. It is essential for them to understand how to manage diverse teams and possess cultural intelligence to succeed in their goals.
3. ***Diversity helps build better strategies:*** Having employees representing communities or locations the company operates in helps to better understand the positive or negative impact on the surroundings by the company's operations, this builds more trust and helps companies to build better strategies to support them.
4. ***Diverse teams are more innovative and better prepared to take bold actions*:** Environmental efforts often require bold actions like rethinking the product design, supply chain, changing behaviours within the organization towards more sustainable choices. It has been proven that ethnic & gender diverse companies are 20% more innovative and 35% more likely to outperform homogenous teams (McKinsey, 2017); when the time comes to take bold actions and solve challenges, diverse teams are simply more prepared.

E #2: Ethics (Equity/Social)

Ethis is, unfortunately, one of the most overlooked aspects while developing sustainable strategies. Ethics is measured by the concept of **social license**, meaning that the company and its measures should be supported by its employees, stakeholders, and the community it operates in. To have an **ethical social impact,** companies need to work on **treating their employees fairly**, promoting **no discrimination policies**, supporting **flexible working hours**, **investing in local communities**, implementing **fair wages**, **ethical sourcing**, understanding the **supply chain**, and so on.

A diverse, equitable, and inclusive workplace improves the ethical or social impact of a company. Here are some ways of how it can be achieved:

1. ***Promoting Equity in the company*, *ensures that everyone has access to the same opportunities and treatment.*** It also enables each individual to participate fully in the company's sustainability efforts. Employees feel valued and heard, therefore, they are much likely to support the measures of the company, and work towards a shared goal.
2. ***Inclusion leads to conscious decision making:*** Leaders who understand the dynamics of inclusive leadership and are aware of their own unconscious bias and privilege, make more conscious and fair decisions.
3. ***Inclusive workplaces have better psychological safety:*** Feeling safe is one of the key human requirements to perform efficiently. When employees feel safe within the company, they can bring their authentic selves to work, share vulnerabilities without fear of repercussions and are not afraid to fail. Thus, increasing the team performance, risk-taking ability and overall employee satisfaction level.
4. ***Diversity and Inclusion help the company reach a wider audience and avoid discriminatory pitfalls*:** Having people from different backgrounds and including minority stakeholders gives the company an insight into the untapped markets, helps identify discriminatory (for example, racist or sexist) products, services marketing campaigns or practices; making the company a responsible brand for its customers and employees.

E #3: Economic

The economic aspect of sustainability is not just about being profitable, but also about **having good governance within the company**. This means that the management and other stakeholders like end-users, value chain, etc. are aligned on common interests. The company is transparent and avoids conflict of interests.

A diverse, equitable and inclusive workplace improves the economic impact of a company. Here are some ways of how it can be achieved:

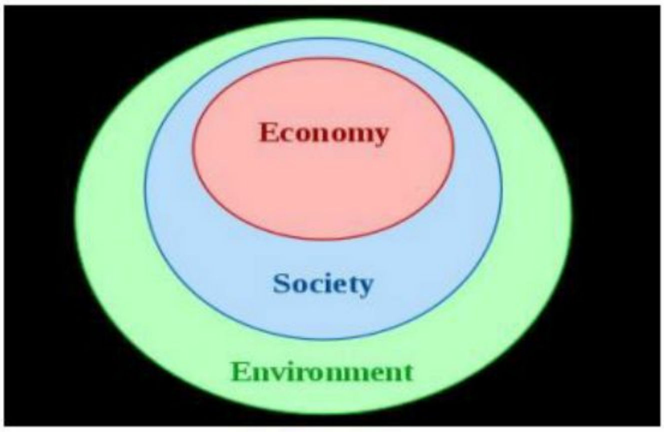
1. ***Diversity with inclusion is profitable for the business:*** Well-managed culturally diverse boards worldwide make 43% higher profits than homogeneous boards. This shows a direct correlation of why diversity is profitable for the business.
2. ***Inclusive organizations promote transparency:*** Inclusive organizations promote equal opportunities and a safe space for everyone, this ensures transparent communication leading to good governance.
3. ***Teams with higher empathy are better equipped to deal with conflict of interests and confrontations*** essential to maintain a fair governance and strong leadership.
4. ***Diverse and inclusive teams promote a trustworthy brand image:*** More diversity and representation within the company means that it is better able to understand different opinions from stakeholders, end-users, value-chain, customers etc. It is, therefore, easy to maintain trust and gain support from others.

To summarize, it is clear how **Sustainability and Diversity, Equity & Inclusion (DEI) are strictly intertwined**. The first step towards implementing a sustainability strategy is to ensure you work on providing your people a workplace where they can be themselves and contribute to their best abilities. Inclusive workplaces ensure that employees have a safe environment to undergo big structural changes and behavioral shifts, turning your sustainability efforts into success.

ENGINEER'S ROLE TO ACHIEVE SUSTAINABLE DEVELOPMENT:

Engineers should carryout their role in abroad context that encompass social, ethical, environmental and economic challenges. These six principles will guide an engineer to achieve sustainable development (Dodds and Venebles, 2005). They will help engineers meet their professional obligations to seek to achieve sustainability, and ensure that this goal is integrated into all their engineering activity. Contribute to building a sustainable society, present and future Engineers have a responsibility to maximize the value of their activity towards building a sustainable world. This requires an under standing of what society demands and what is achievable, and are cognition that these change overtime. They should.

- Recognize that though their activity may be local and immediate, the potential impacts of their work may be global and long-lasting
- have an understanding of other relevant social and cultural structures outside their own normal community of practice
- understand their important role in the sustainable development of communities
- recognize the impacts of an engineering project on communities, global or local, and incorporate the views and concerns of the communities



Apply professional and responsible judgment and take a leadership role Engineering is a profession with a strong ethical dimension. Engineers have an important role in providing solutions to the problems such as poverty, under-development and environmental degradation. Therefore the professional engineers should:

- look at the broad picture
- ensure that their knowledge about sustainable development is up-to-date
- be prepared to influence the decision-maker for a project
- Identify all the issues and options to the decision-maker about a projects of that decisions are soundly based
- Identify options that take account of economic, social and environmental outcomes
- Ensure that offered solutions and options will contribute to sustainability
- Be aware that there are inherently conflicting and un-measurable aspects of sustainability Do more than just comply with legislation and codes In seeking sustainable solutions, complying with current legislation, codes and environmental protection regulations may not be sufficient.

Therefore engineers should:

- Go beyond the minimum wherever possible, anticipating future legislation which may be stronger
- By their example, help others improve their performance
- Alert the relevant authorities if there are deficiencies in legislation and if sustainable solutions and outcomes could been dangered by regulatory change
- Use their technical expert is to drive new legislation and codes Use resources efficiently and effectively Engineers have as towards hip role with respect to planetary resources, and a responsibility to society to create more useful products and services with the lowest possible consumption of raw materials, water and energy.

This requires them to:

- Understand that there are environmental limits and finite resources
- Reduce resource demand by using less in the first place

- Reduce waste production by being efficient with resources that are used
- Use systems and products that reduce embedded carbon, energy and water use, waste and pollution
- Adopt strategies for re-use, recycling, decommissioning and disposal of components and materials
- Minimize any adverse impacts on sustainability at the design stage
- Work to repair any damage

Seek multiple views to solve sustainability challenges :

The increasing complexity of sustainability challenges means that engineers working alone cannot solve all the challenges that we face. Therefore it is important for engineers to:

- Engage with stakeholders, listening and recognizing the value of the perspectives of others, including non-specialists
- Avoid working in isolation, involving other professionals at all stages of a project
- Utilize cross-disciplinary knowledge and diverse skills
- Promote the important leadership role of the engineer in finding solutions to sustainability challenges for the benefit of society
- Seek a balanced approach

Manage risk to minimize adverse impact to people or the environment

Engineers are routinely involved in planning and managing projects where they should:

- Harness their skills to minimize damage to people or the environment from engineering processes and products
- Undertake a comprehensive risk assessment before a project begins
- Ensure that the risk assessment includes the potential environmental, economic and social impacts, beyond the lifetime of the engineering project

PROFESSIONAL ORGANIZATIONS FOR ENGINEERS

Engineering professional organizations provide important support to engineers. These groups work to advocate on behalf of engineers, provide professional development opportunities, publish updates on the latest innovations, and connect engineers to the community. Anyone pursuing a Master of Engineering Management degree would benefit from becoming a member of at least one of these organizations. Below find the top 5 engineering associations, which serve both the general profession of engineering as well as specific industries within the field.

- National Society of Professional Engineers
- IEEE
- American Association of Engineering Societies
- Society of Women Engineers
- International Engineering Consortium

Learning about five great professional organizations for engineers is the first step that any engineering graduate should undertake after graduating from college. Whether a professional is a man or a woman, looking for a nontechnical organization or a global consortium with international work opportunities, there is an organization that will fit the needs of every engineering. Here are some of the top organizations that are highly rated by current professionals in the field.

1. National Society of Professional Engineers

The National Society of Professional Engineers was established in 1934 and is one of the only professional organizations for engineers that has stated goal of addressing the non-technical concerns of professional and licensed engineers. It is a multidisciplinary national organization that encourages its members to discuss and critique its ability to create change for them within the field as well as providing continuing education and networking opportunities to support better career mobility. It is currently one of the only nontechnical organizations in the country to support engineers.

2. IEEE

The IEEE is noted for being the world's largest technical professional organization that prides itself on the advancement of technology in all fields of engineering. With over 420,000 members spanning 160 countries, it is an international organization that is active in corporate identity, governance, global public policy, and education. The IEEE is also renown for its collection of publications and conferences that often lead to employment opportunities for its members; professional engineers often cite the society as one of the first memberships they obtain after graduating from college, reinforcing the idea that a global network of engineers is a necessary step in evolving the field of engineering.

3. American Association of Engineering Societies

The American Association of Engineering Societies was established in 1979 is one of the five best professional organizations for engineers; it is a multidisciplinary organization that is dedicated to the knowledge and practice of the field. It is also known for providing access to all professionals in the field, including educators, government workers, and researchers. It is a nonprofit organization that aims to be a collective voice for the engineering community within the United States. The group also has a stated goal of working with international engineering societies, enabling the free flow of information and technology between countries, making it an exciting network for any professional.

4. Society of Women Engineers

The Society of Women Engineers focuses on women within the field; it is an association that delivers continuing education as well as networking opportunities to its members. It is one of best professional organizations for engineers because it provides leadership workshops, educational programs, and more in an inclusive manner for women who are interested in becoming the best in the field. Membership to the society includes resources, debate forums, awards and recognition programs, publication opportunities and more, enabling women engineers to do everything from further their career to opening up discussions about diversity in STEM.

5. International Engineering Consortium

The International Engineering Consortium was established in 1944 and is the leading nonprofit organization that brings together both universities and engineering societies for the purpose of the continuing education of engineers. By offering engineers the chance to take on post-professional education through its programs, the consortium is ensuring that the field continues to evolve as the understanding of engineering changes with new advancements and technologies. The IEC is also the head of the Electrical and Computer Engineering Department Heads Association, which is dedicated to sharing information among American Universities about the industry and any changes it encounters, passing that information down to students at the undergraduate and graduate levels.