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Global Advances in Engineering Education

Edited by
J. P. Mohsen, Mohamed Y. Ismail,
Hamid R. Parsaei, and Waldemar Karwowski

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Preface

Engineering education either in its classical training forms or more traditional hands-on and apprenticeship methods has been around for over several thousand years. Engineers by and large are credited for creating public infrastructures which in turn lead into national prosperity and advancement of communities. Academic education to train competent engineers has been the subject of numerous books, articles, and global technical conventions and symposia. The need to produce well-trained and properly educated engineers with vast problem-solving and communication skills with clear appreciation of their societal and ethical responsibilities has been the subject of many academic debates. Engineering trainings regardless of their focus and specializations have always been publicly perceived as demanding and often require strong background in mathematics and basic sciences.

Over the past five decades with the advent of space discovery and the development and introduction of mobile and wireless communications, engineering fields in general have achieved significant public recognition. To encourage more high-school students to attend engineering and science-driven fields, several STEM (Science, Technology, Engineering, and Mathematics) initiatives have globally been introduced. To make STEM more attractive and accessible to new generations, new delivery methods such as "flipped classrooms," online and web-based instructions were introduced and their effectiveness in retaining the information has been investigated by many researchers. Historically, research on engineering education has been carried out by social scientists; however, over the past three decades the engineering education research has rightfully earned its position among applied science disciplines and many research journals reported such research progress.

This edited volume is intended to report on some of initiatives and activities undertaken and the outcomes achieved by some academic researchers in several different counties from around the globe. Although the chapters on various issues on engineering education, they collectively report on the advancements made and results achieved by different approaches adopted by several academic practitioners to create a new paradigm for educating and training new engineers. Although developing and implementing creative ways to attract and train new generation of engineers is a dynamic process, sometime a small subset gets reported in books and literature. We are confident the journey continues and more creative approaches will get documented in future publications.

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Dr. Mohsen was named Engineer of the Year in Education by the Kentucky Section of ASCE in 1999 and received the University of Louisville Distinguished Service to the Profession Award in 1999 and the Distinguished Teaching Professor Award in 2003. In 2014, he received the ASCE Computing in Civil Engineering Award. He is a Fellow of ASEE as well as a Fellow of ASCE.

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chapter one

History of engineering education

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Contents

1.1 Prologue: Engineering and the cradle of civilization

With the existence of the first man on earth, his survival was very much linked, dependent on, and correlated to his efforts and success on how to adapt and conquer his surrounding environment and the unfriendly natural phenomena. Thus, he always strived to apply the knowledge he gained to use his physical power, the materials, and other resources around him to make his life easier. Engineering is defined, according to the Encyclopedia Britannica, as "the application of science to the optimum conversion of the resources of nature to the uses of humankind." If we agree on such a generic definition, we may discover that engineering as a science and art, and as we know it today, actually was, implicitly and partially, there from the beginning of written history.

To elaborate more on the meaning and spread of the term "engineering," we may extend it to encompass the application of mathematics, science, economics, experimentation, social, and practical knowledge to design, construct, maintain, and improve structures, machines, systems, components, tools, materials, processes, and organizations.

It is hard to state, however, where and when engineering started historically. Was it near the banks of the great Nile River where the ancient Egyptians built their gigantic temples, like the one shown in Figure 1.1, and the great cities like Thebes (Luxor) and Memphis (near south of modern Cairo) some 3,000 years BC? Was it in the valley of

Figure 1.1 Entrance to the Luxor Temple in Egypt. (By MusikAnimal—Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=41830942.)

Tigris and Euphrates rivers, this vast area which was historically known as Mesopotamia (most of current Iraq, plus smaller parts of Syria, Iran, Turkey, and Kuwait), where Sumerians and Akkadians (ancestors of Iraqis) gave birth to the world's first cities, and the cuneiform scripts the predecessor of most of the ancient world alphabets?

Alternatively, was it in the same region where the invention of the wheel as a circular element intended to rotate on an axle bearing, led to the world's first transportation device? Or was it where ancient Babylonians have once established the legendary hanging gardens of Babel shown in Figure 1.2, to be one of the Seven Wonders of the old world? Or was it where the Phoenicians gave birth to other alphabets in Lebanon, during almost the same time, and drove their ships in the Mediterranean Sea as clever and experienced sailors?

Ever since those ancient epochs, if we want to follow the steps of engineering education and how it evolved, we have to assume that as long as there was a lasting monument, a durable structure, and an enduring construction, there should be a form of engineering science. That form of science has been transferred systematically to and practiced by the workforce, foremen, supervisors, designers, and executives who erected those shrines along history. One may conclude that to have, for instance, an everlasting construction as those existed over centuries, this required precise measurement, materials science, metallurgy for hard tools, organization

Figure 1.2 Hand-colored engraving of the legendary Hanging Gardens of Babylon, with the Tower of Babel in the background. (By Maarten van Heemskerck—http://www.plinia.net/wonders/gardens/hgpix1.html, Public domain, https://commons.wikimedia.org/w/index.php?curid=65909.)

structure, material handling equipment, and sometimes knowledge of trigonometry and principles of mechanics.

In this chapter, the analysis of the history of engineering education is actually a study of the evolution of physics, chemistry, philosophy, geometry, astronomy, mathematics, and logic sciences, because all of these disciplines were practiced by most of the men of wisdom in ancient times. Moreover, these forms of human knowledge present the backbone of engineering as we know it today. This chapter also focuses on the main contributions in fields related to engineering and not the biographies neither of the developers nor the political leaders. It presents a chronological study of the achievements of the world from the perspective above. The study marked the pioneering efforts, brilliant contributions, and breakthrough inventions. It is not intended to be encyclopedic in nature, which means that some of the places, dynasties, and engineering achievements would not be covered due to the limited space allocated to this chapter. Nevertheless, we believe that such an issue could be widely discussed and it could be the subject matter of a more comprehensive work. It is rather impossible to elaborate on every engineering and engineering education aspects in history. However, we have tried to mention, from the previously mentioned perspective, the first recorded effort and contribution across the history of humanity. Since our focus is history, we care much to mention the questions of when, where, and in what discipline was the original contribution. We were not concerned about what is the current status of that old or ancient innovation at least that was the priority we try to adhere to. Did those criteria make sense? It is the reader who will figure out the answer to the aforementioned question.

1.2 Engineering in ancient Egypt

We start with engineering in ancient Egypt thousands of years BC, where no schools or universities exist at that time. However, one could not imagine that a megastructure and a super project like the great pyramid of Giza, which is branded as the pyramid of Khufu (also known as Cheops), was designed and built without an engineering science and background. Exactly how it was built, what was the true reason for constructing such an enormous building, still puzzles people today. Although known as a multitalented and iconic historical figure, Imhotep (about 2,600 BC), who devised a means of creating the step pyramid of Saqqara for his king Dzjoser (Figure 1.3), has never been mentioned to have an engineering background. Moreover, there is no record that the chief designer and architect of the great pyramid did receive any formal engineering education like what we know nowadays.

Figure 1.3 The Step Pyramid of Dzjoser at Saqqara, Egypt. (By Dennis Jarvis from Halifax, Canada—Egypt-12B-021-Step Pyramid of Djoser, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=66938816.)

The secret of mastering those ancient stunning engineering achievements is still a mystery, but we may observe that the knowledge behind such scientific miracles was not recorded on the walls of the temples or found in the buried tombs discovered beneath the hot sands of the deserts.

One may assume that there was science, theories, mathematics, and geometrical advances which form the bases and foundation for such incredible monuments.

Consequently, the direct conclusion is that there was an engineering education, in a way or form that explains the aforementioned huge outcomes. We may also conclude that inside the sacred temples of ancient Egypt, and similar holy places, such teachings were in the hands of the priests of Amen-Ra who were the sole source of knowledge, wisdom, and sometimes political power.

The only explanation for not being revealed is that it was an art, science, and knowledge that should not be disseminated, publicized, or transferred by any means because it was a source of power and it was closely related to their religion and divine beliefs.

Ancient Egyptians strongly believed in the idea of immortality derived from religious roots. This idea was the main reason behind the selection of very hard building materials (e.g., granite) to build their temples and tombs and to discover appropriate technologies to cut, shape, transport, and install massive amounts of stones.

1.3 Academy of Athens, Greece

During the 8th-century BC, the Greeks started to use the Phoenician (ancestors of the Lebanese) alphabet and adapted it to their own language, creating the first “true” alphabet. A process was needed to establish the Greek’s unique contribution to human scientific knowledge heritage. As one of the oldest in the world, Plato established his Academy in Athens, Greece around 387 BC (Figure 1.4). Aristotle (384–322 BC) studied there for 20 years before founding his own school, the Lyceum. The Academy persisted throughout the Hellenistic period as a skeptical logic school. Among the attendees of such an Academy “Akademia” was Theaetetus of Sunium (417–368 BC), a mathematician whose principal contributions were on irrational lengths, which was included in Euclid’s *Elements*. His teacher, Theodorus of Cyrene, had explored the theory of incommensurable quantities. Archytas (428–347 BC) was a philosopher, mathematician, and astronomer. He was also a scientist of the Pythagorean school (due to Pythagoras 570–495 BC) and famous for being the reputed founder of mathematical mechanics. Archimedes of Syracuse (287–212 BC), as shown in Figure 1.5, was a mathematician, physicist, engineer, inventor, and astronomer. He is considered one of the leading scientists in the ancient world and one of the greatest of all time. Archimedes anticipated

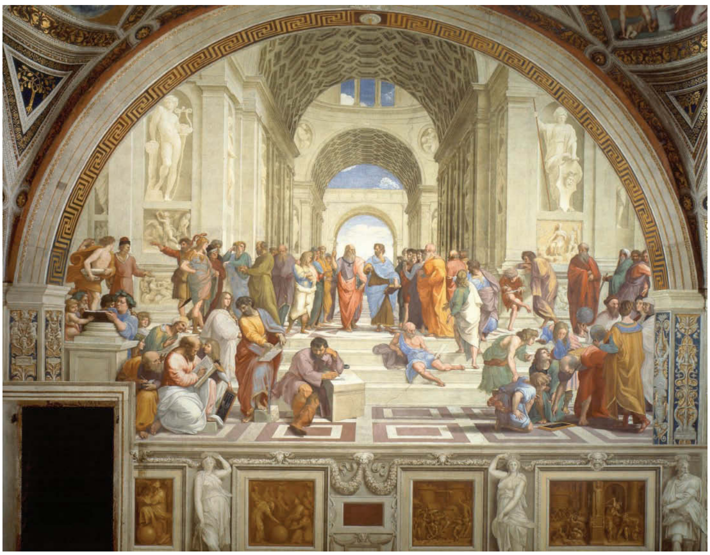

Figure 1.4 “Scuola di Atene,” The School of Athens. (By Raphael—Stitched together from vatican.va, Public Domain, https://commons.wikimedia.org/w/index.php?curid=4406048.)

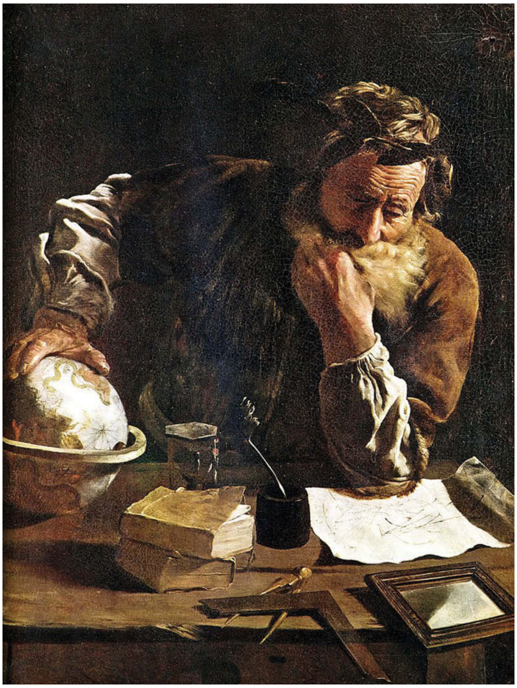

Figure 1.5 Archimedes Thoughtful by Fetti (1620). (By Domenico Fetti—http://archimedes2.mpiwg-berlin.mpg.de/archimedes_templates/popup.htm, Public Domain, https://commons.wikimedia.org/w/index.php?curid=146592.)

modern calculus and analysis by applying concepts of infinitesimals and the method of exhaustion to derive and rigorously prove a range of geometrical theorems, including the area of a circle, the surface area and volume of a sphere, and the area under a parabola. The Archimedes' screw is still in use today for pumping liquids and granulated solids such as coal and grain. Autolycus (360–290 BC) was an astronomer, mathematician, and geographer. The lunar crater Autolycus was named in his honor.

The Academy of Athens had its strong influence on the lifestyle of ancient Greek people and it shaped the free-thinking environment at that time. The result was a great evolution in mathematics, philosophy, geometry, astronomy, and other facets of knowledge which, as already stated, created the backbone of any formal engineering education and consequently accomplishments.

As a model, the Parthenon shown in Figure 1.6 is an ancient temple on the Acropolis, Greece, which was constructed between 447 and 432 BC. It represents the most important remaining and enduring building of ancient classical Greek architecture and art. Callicrates and Ictinus, who

Figure 1.6 The Parthenon showing the common structural features of ancient Greek architecture. (By Steve Swayne—File:The Parthenon Athens.jpg Wikimedia Commons, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=22556135. From Travelers in the Middle East Archive (TIMEA). http://hdl.handle.net/1911/9303. By Antonio Tempesta (Italy, Florence, 1555–1630), Public Domain, https://commons.wikimedia.org/w/index.php?curid=27300728.)

both lived in the middle of the 5th-century BC, were considered to be the first architects of the Parthenon.

1.4 The city of Alexandria

Alexander the Great founded the city of Alexandria in 323 BC near the western branch of the Nile on a site between the sea and Lake Marriott, linking the island of Pharos to the mainland of Egypt. The urban plan of the city was set by Alexander's Architect Dinocratis, who designed it to have unique features. Unlike other older cities, Alexandria was remarked by its two straight long streets: one parallel to the Mediterranean Sea shores from east to west and the other a perpendicular crossroad as illustrated in Figure 1.7.

Alexander built other cities carrying his name. Around 15 other "Alexandria" cities were originally founded by Alexander in his vast campaign during the 3rd-century BC. More than double that number of cities carry the same name, "Alexandria," in all continents. However, after more than 23 centuries, Alexandria of Egypt remains the largest and the most famous. On the other hand, and despite its current overwhelming population together with the expansion of the city to the east and west, Alexandria, as its old city version, still carries the same urban design characteristics intended by its founders.

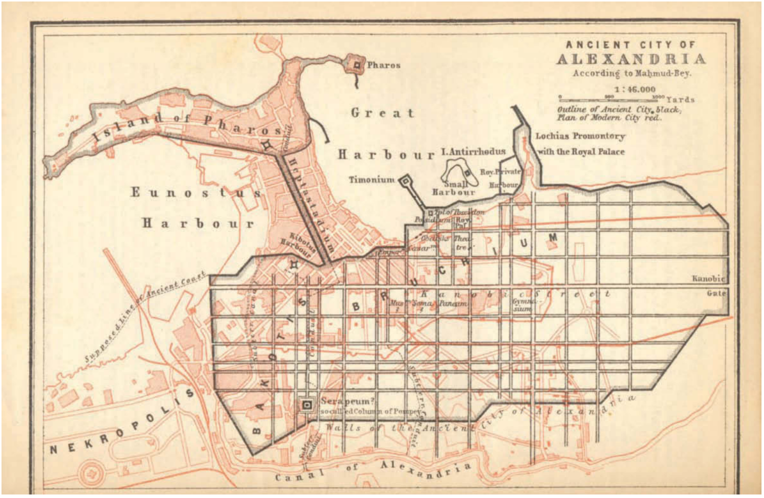

Figure 1.7 Plan of the ancient city of Alexandria.

Figure 1.8 An imaginary illustration of the ancient lighthouse of Alexandria.

Another great engineering achievement was the establishment of the ancient lighthouse of Alexandria, which was located in the western parts of ancient Alexandria and shown in Figure 1.8. It is known as Pharos of Alexandria and is one of the Seven Wonders of the World and the most famous lighthouse in antiquity. It was a technological triumph in its time and is the archetype of all lighthouses since. Built by Sostratus of Cnidus, the architect of Ptolemy I Soter, it was finished during the reign of Soter's son Ptolemy II of Egypt in about 280 BC.

1.5 Bibliotheca Alexandrina "Ancient Library of Alexandria"

The ancient library of Alexandria, known as the *Bibliotheca Alexandrina*, was the most famous and the largest library in the old world. The library formed part of a great research institute at Alexandria in Egypt that is known as the Ptolemaic "Mouseion" Academy. The expression "Mouseion" was slanted to "museum" as we know it today. Ptolomy I "Soter," who ruled after Alexander, started to build the library around 295 BC. He wanted to found an educational facility in the Greek style, similar to Aristotle's institute named as the "Lyceum" in Athens. He assumed that this place would attract great scholars from all over the world. The initial design shown in Figure 1.9 is attributed to Demetrius Phalereus and is estimated to have stored at its peak 400,000–700,000 parchment and papyri scrolls. Bibliotheca Alexandrina attracted many full-time researchers, scientists,

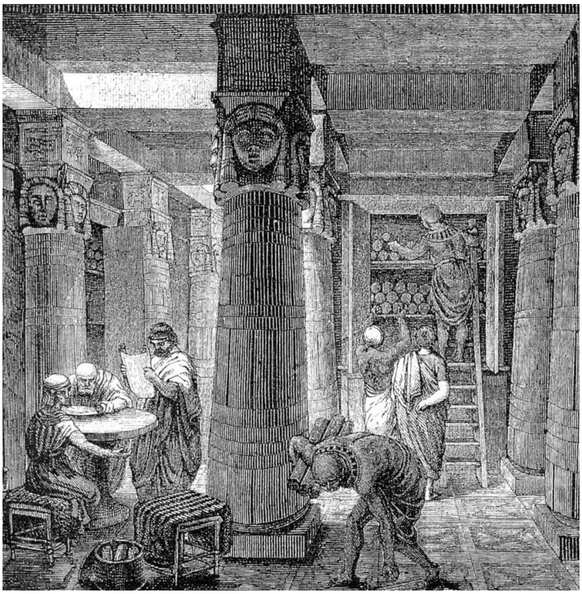

Figure 1.9 An imaginary illustration of the ancient Library of Alexandria, Egypt. (By O. Von Corven—Tolzmann, Don Heinrich, Alfred Hessel and Reuben Peiss. The Memory of Mankind. New Castle, DE: Oak Knoll Press, 2001, Public Domain, https://commons.wikimedia.org/w/index.php?curid=2307486.)

and students for three centuries to create top-notch education at that time. Supported by state stipends that helped them maintain the scrolls, translate and copy them, and conduct research. As time went on, the city opened another branch of the library at the Temple of Serapis.

It should be mentioned that major contributors to mathematics, science, and engineering lived most of their lives in Alexandria. Big Names like Euclid was born and died in Alexandria (323 and 285 BC), often referred to as the “founder of geometry” or the “father of geometry.” Apollonius of Perga was a geometer and astronomer known for his theories on the topic of conic sections, died in Alexandria 190 BC. Hero of Alexandria (10–c. 70 AD) was a mathematician and engineer, who was the representative of the Hellenistic scientific tradition. Hero published a well-recognized description of a steam-powered device sometimes called a “Hero engine.” Eratosthenes of Cyrene, who died in Alexandria, 194 BC, was known as a scientific writer, astronomer, and the one who made the first measurement of the size of the Earth. Theon of Alexandria was a mathematician and astronomer who is best remembered for the part he played in the preservation of Euclid’s Elements. Theon’s daughter Hypatia, born and died in Alexandria (355–415), was known as the earliest female mathematician, astronomer, and philosopher. Historically, the vanishing of the ancient library of Alexandria is a mystery. However, it was mentioned that the library had been burned to the ground several times in the early centuries AD.

1.6 Engineering in ancient Rome

For almost a millennium, ancient Rome, as the capital of an empire, controlled the destiny of all civilization extended from what is known as Europe, north, south, and east Mediterranean nations. On the other hand, Rome’s early development has been largely influenced by those civilizations in Greece, Carthage, Egypt, Phoenicia, and Persia. The ruins leftover in several countries which carry the features and characteristics of Roman culture, design, and architecture are living examples of how such mutual influence exists. The city of Rome itself holds a vast number of lasting monuments, tributes, temples, and memorials that indicate a sophisticated engineering science and technology even as we recognize it nowadays.

One example is the Colosseum (c. 70–82 CE), shown in Figure 1.10, which was built during the Flavian dynasty of emperors. The oval stadium measures about one-half of a kilometer around, with external dimensions of 190 by 155 m. The approximately 48-m facade has three superimposed series of 80 arches and an attic story. The façade also included sunshades to protect the 50,000 seats from the sun during the gladiatorial contests, combats with wild animals, and false battles.

For more than 1,000 years, the Colosseum was a famous symbol of Rome, and it had been a sort of entertainment for the people of the city. Once again,

Figure 1.10 A 4 × 4 segment panorama of the Colosseum at dusk. (By Diliff—Own work, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=2127844.)

an unbiased analysis would conclude that such an unprecedented structure would not be designed, erected, and maintained without a proper kind of engineering and technology-based experience and knowledge which should have been disseminated by an anonymous mentor to his followers. The list of similar engineering contributions includes tens if not hundreds, for example, the Roman contribution in the design and the construction of bridges is enormous. For instance, the several bridges along the Tiber River built about the time of Hadrian (reigned 117–138 AD) (Figure 1.11).

Figure 1.11 Saint Angelo Bridge over the Tiber River, Rome, Italy. (By Jebulon—Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=30172578.)

1.7 Medieval Bagdad and the House of Wisdom

The Abbasid Empire (762–1258) was the wealthiest, luxurious, and dominant political power in its time reaching from the western Mediterranean to India. Enormous wealth had flowed into the new capital of Baghdad since its foundation in 762. Science, philosophy, and arts were very much encouraged during the reign of Al-Maʾmūn who ruled (813–833).

Al-Maʾmūn encouraged the translation of Greek philosophical and scientific works and founded an academy called the House of Wisdom (Dar al-Ḥikmah) to which the translators, most often Christians, were attached. He also imported manuscripts of particularly important works from Byzantium. Examples are the writings of: Diocles' treatise on mirrors, Theodosius's Spherics, Pappus's work on mechanics, Ptolemy's Planisphaerium, and Hypsicles' treatises on regular polyhedra (of Euclid's Elements) were among those translated. Al-Khwārizmī, (780–850), who worked in (Dar al-Hikma), was a mathematician and astronomer. Al-Khwārizmī introduced Hindu–Arabic numerals and the concepts of algebra that his name was the origin of the terms *algorithm* and *algebra*. Other famous scholars during that period were Thābit ibn Qurrah (836–901), a mathematician, astronomer, physician, and philosopher. Also, Abūʾl-Wafāʾ (940–997) and Omar Khayyam (1048–1131) were capable mathematicians who solved the general problem of extracting roots of any desired degree. Geometry also went through extensive development by Ibrāhīm ibn Sinān (909–946), Abū Sahl al-Kūhī (died c. 995), and Ibn al-Haytham. They solved problems involving the pure geometry of conic sections, including the areas and volumes of plane and solid figures formed from them, and also investigated the optical properties of mirrors made from conic sections.

1.8 Engineering in Andalusia (ancient Spain)

Andalusia in Spain became part of the independent Umayyad caliphate of Córdoba, which was founded by ʿAbd al-Raḥmān III in 929. Despite its political instability, scholars have seen the medieval period as the golden age of Andalusia because of its economic prosperity and its brilliant cultural blossoming. Agriculture, mining, and industry flourished as never before. The cities of Córdoba, Sevilla, and Granada became eminent centers of architecture, science, and learning at a time when the rest of Europe was still emerging from the Dark Ages. The Mosque-Cathedral of Córdoba shown in Figure 1.12 and the fortress-palace of the Alhambra in Granada shown in Figure 1.13 were built during this period, and the great Spanish Muslim philosopher Averroës (Ibn-Rushd) was perhaps its leading intellectual figure.

Figure 1.12 Cathedral–Mosque of Córdoba, Spain. (By Michal Osmenda from Brussels, Belgium—Cathedral–Mosque of Córdoba, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=24415630.)

Figure 1.13 Alhambra de Granada, Patio de los Leones (Courtyard of the Lions), Spain. (By Allie Caulfield—originally posted to Flickr as 2002-10-26 11-15 Andalusien, Lissabon 075 Granada, Alhambra, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=5780894.)

1.9 Engineering in Medieval Europe

One area in which engineering made substantial advances was the construction of cathedrals, castles, and other large structures. Cathedrals were built in the Romanesque style (10th and 11th centuries) and later in the Gothic style (12th–16th centuries).

Another aspect in which engineering made significant progress in medieval Europe was the design and construction of sailing vessels. This led to progress in maritime, and naval construction during that time, first by Spain and Portugal and later by England, set the stage for European exploration and colonization in North and South America, Africa, and Australia.

As for engineering education, one may remark that the first recorded university in Europe was in Bologna, Italy in the 9th century. Although specialized only in Roman law at that time, it is considered the oldest university in continuous operation, as well as one of the leading academic institutions in Italy and Europe.

The historic University of Paris (French: Université de Paris) first appeared in the 12th century, The university is often referred to as the Sorbonne (Collège de Sorbonne) founded in 1257, but the university as such was older and was never completely centered on the Sorbonne.

The University of Paris (along with that of the University of Bologna) became the model for all later medieval universities in Europe.

University of Oxford, England, is also one of the world's old universities that were established in the 12th century as a model of the University of Paris which has gained its reputation from its teachings in theology, law, medicine, and liberal arts. However, both universities were considered centers for mathematics and philosophy. Of particular importance in these universities were the Arabic-based versions of Euclid, of which there were at least four by the 12th century. Of the numerous revisions which were made, that of Johannes Campanus (c. 1250; first printed in 1482) was easily the most popular, serving as a textbook for many generations. Studies of what is now called physics were conducted by Thomas Bradwardine, who was active in Oxford, in the 14th century, as one of the first medieval scholars.

After leaving Paris, Roger Bacon conducted his scientific experiments and lectured at Oxford from 1247 to 1257. Bacon was one of several influential scientists at Oxford during the 13th and 14th centuries. Although departments of engineering science were founded lately with the beginning of the 20th century, it is likely that engineering-related topics were taught and studied at Oxford before that time. Physical sciences were taught and studied at Oxford from at least the 17th century.

The start of Cambridge University was also in the 12th century when scholars from Oxford transferred to Cambridge. Cambridge remained fairly insignificant until about the mid of the 17th century when the professorship of mathematics was handed to Isaac Newton. Newton held the chair for over 30 years and gave the study of mathematics a unique position in the university. He was the eminent figure of the scientific revolution of the 17th century. In optics, his discovery of the composition of white light integrated the phenomena of colors into the science of light and laid the foundation for modern physical optics. In mechanics, his three laws of motion, the basic principles of modern physics, resulted in the formulation of the law of universal gravitation. In mathematics, he was the original discoverer of the infinitesimal calculus.

In medieval and Renaissance Germany, a set of universities were established with the same theological model. One may list Heidelberg University (established in 1384), Leipzig University (1409), and University of Rostock (1419) and a few others. A notable remark here is that some of those universities encompass no explicit engineering departments, even in their current versions. However, engineering closely related fields like mathematics, physics computer science, and economics, are existent.

1.10 Engineering in Asia

1.10.1 The Great Wall of China

As one of the Seven Wonders of the World, the Great Wall of China, shown in Figure 1.14, is an outstanding representative of those famous constructions in China. It was built to be a defensive structure to keep intruders

Figure 1.14 The Great Wall of China. (By Photo by © CEphoto, Uwe Aranas, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=32396893.)

from entering the mainland. The construction of the Great Wall began in the 3rd century, and the whole construction project lasted for an entire century, through different dynasties. Finally, this mega structure stretches with a total length of 8851.8 km from west to the east of China, and that traverses nine provinces and municipalities.

1.10.2 Forbidden City, Beijing—China

Known as the Imperial Palace Museum, the Forbidden City shown in Figure 1.15 is a magnificent building complex located in the very heart of Beijing. As the symbol of imperial power, which was built during the Ming Dynasty (1406–1420 AD), it is the largest and well-preserved wooden building complex of the world and is considered a distinguished sample of the traditional Chinese palatial architecture.

1.10.3 Other engineering-related contributions in China

Confirmed by archaeological evidence, the earliest cast iron was developed in China by the early 5th-century BC during the Zhou Dynasty (1122–256 BC), the oldest specimens found in a tomb in Jiangsu province.

The earliest evidence of bronze crossbow bolts dates as early as the mid-5th-century BC in ancient China. Even earlier, paper pulp preparation

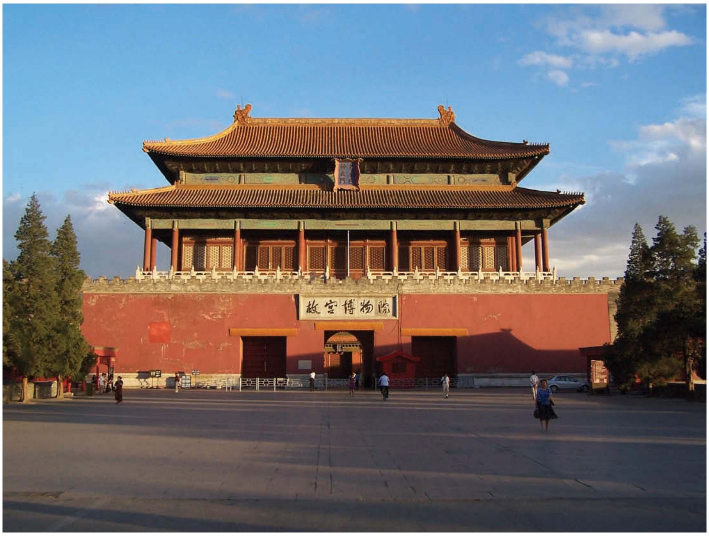

Figure 1.15 Forbidden City Beijing Shenwumen Gate, China. (By user:kallgan—Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=978574.)

processes and the raw material used in making paper were invented during the Han Dynasty in the 2nd-century BC The birth of paper, as we know it today, took place under the Chinese Han Dynasty in AD 105. Ts'ai Lun, a court official, invented a papermaking process which primarily used rags (textile waste) as the raw material with which to make paper.

1.10.4 Taj Mahal, India

The Taj Mahal, a mausoleum complex in Agra, Northern India and shown in Figure 1.16, has been distinguished as the finest example of Indian, Persian, and Islamic blend of architectural styles. The Taj Mahal is also considered to be one of the most beautiful structural compositions and most iconic monuments in the world today. The plans for the complex have been attributed to various architects of the period, though the chief architect was probably Ustad Aḥmad Lahawrī, an Indian of Persian descent in about 1632. More than 20,000 workers were employed from India, Persia, the Ottoman Empire, and Europe to complete the mausoleum and the adjunct buildings with the decoration work continued until at least 1647.

1.10.5 Nalanda, Bihar, India

Now in ruins, Nalanda used to be a thriving center of learning from the 7th-century BC to 1200 CE attracting students and scholars from across

Figure 1.16 Taj Mahal with Taj Mosque. (By Biswarup Ganguly, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=35528211.)

Figure 1.17 The ruins of ancient Nalanda in Bihar, India. (By Michael Eisenriegler from Vienna, Austria—Nalanda, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=37199366.)

the subcontinent and from as far away as Tibet, China, Korea, and Central Asia. Though the ruins shown in Figure 1.17 occupy an area of just approximately 12 ha, the university once occupied a larger area and consisted of meditation halls, classrooms, temples, and dormitories for over 10,000 students and 2,000 teachers.

1.10.6 Blue Mosque, Turkey

The Blue Mosque, as it is popularly known, or Sultan Ahmet Mosque, shown in Figure 1.18 was constructed between 1609 and 1616 during the rule of Ahmed I. It was designed by the architect, Sedefkar Mohmed Agha, an apprentice of "Sinan Agha the Grand Architect" (1488–1588) who was the chief architect and civil engineer for the sultans during his life period.

1.10.7 Persepolis, Persia (ancient Iran)

Persepolis was the capital of the Achaemenid Empire which is the First Persian Empire (ca. 550–330 BC). It is situated 60 km northeast of the city of Shiraz in Fars Province, Iran. The earliest ruins of Persepolis date back to 515 BC. It represents the Achaemenid style of architecture. UNESCO declared the ruins of Persepolis that shown in Figure 1.19, a World Heritage Site in 1979.

Figure 1.18 The Blue Mosque, Istanbul, Turkey. (By Kamiox—Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1331312.)

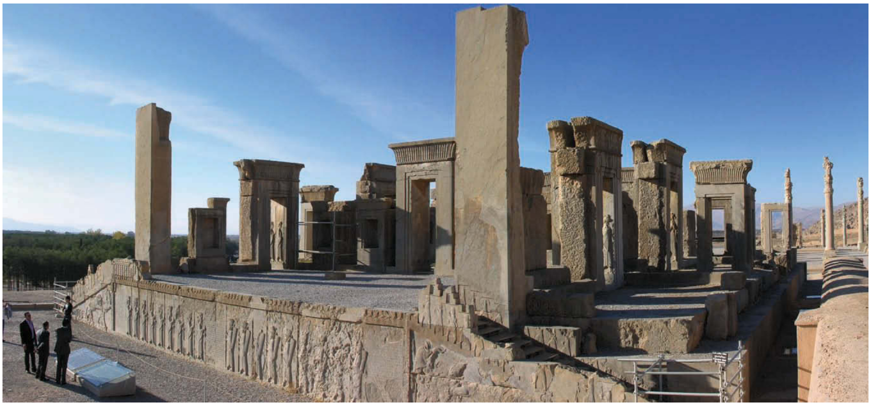

Figure 1.19 Ruins of Tachara, Persepolis (ancient Persia). (By Hansueli Krapf—File:2009-11-24 Persepolis 02.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=47322612.)

The city includes a 125,000 m^2 terrace, partly artificially constructed and partly cut out of a mountain, with its east side leaning on a mountain. The other three sides are formed by retaining walls, which vary in height. Rising from 5 to 13 m (16–43 ft) on the west side was a double stair. From there, it gently slopes to the top.

1.11 Engineering during the European Renaissance

Viewed as the passage between the medieval and the modern age, the renaissance is a remarkable milestone in the timeline of Europe's history, which took place between the 14th and 17th centuries. It appeared in Italy as a drastic change in culture, arts, science, and other facets of human lifestyle. From Italy, such a phenomenon was extended to the rest of Europe, until the beginning of the industrial revolution era. During the Renaissance, engineering contributions to mankind were significant. Iconic figures such as Leonardo da Vinci (1452–1519 BC), shown in Figure 1.20, and his substantial achievements in arts, architecture, civil engineering, geology, optics, and hydrodynamics are milestones in world engineering history. In addition to his great paintings such as

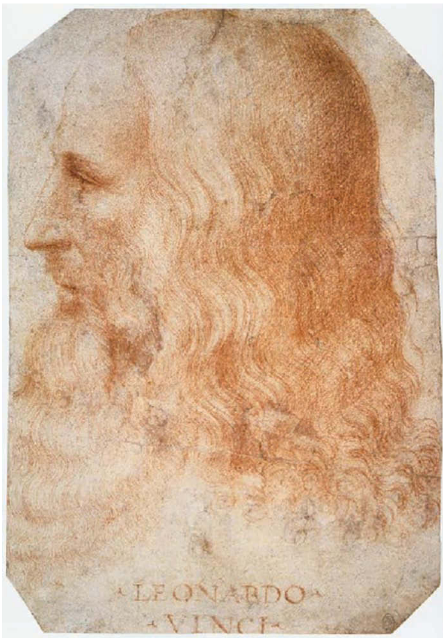

Figure 1.20 Leonardo Da Vinci. (By Francesco Melzi, Public Domain, https://commons.wikimedia.org/w/index.php?curid=15498000.)

the *Mona Lisa*, regarded as the most famous portrait of a human figure and the Last Supper the most reproduced religious painting of all time, Da Vinci is also known for his technological inventions in a significant number of different engineering-related areas. He conceptualized a flying machine that is illustrated in Figure 1.21, which may be considered the ancestor of the helicopter, and the device was outlined to be built of wood, reeds, and clothing. Leonardo also envisioned a type of armored fighting vehicle, the origin of the same current military gadget. He also drafted a concentrated solar power which is a system to generate solar power by using mirrors or lenses to concentrate a large area of sunlight,

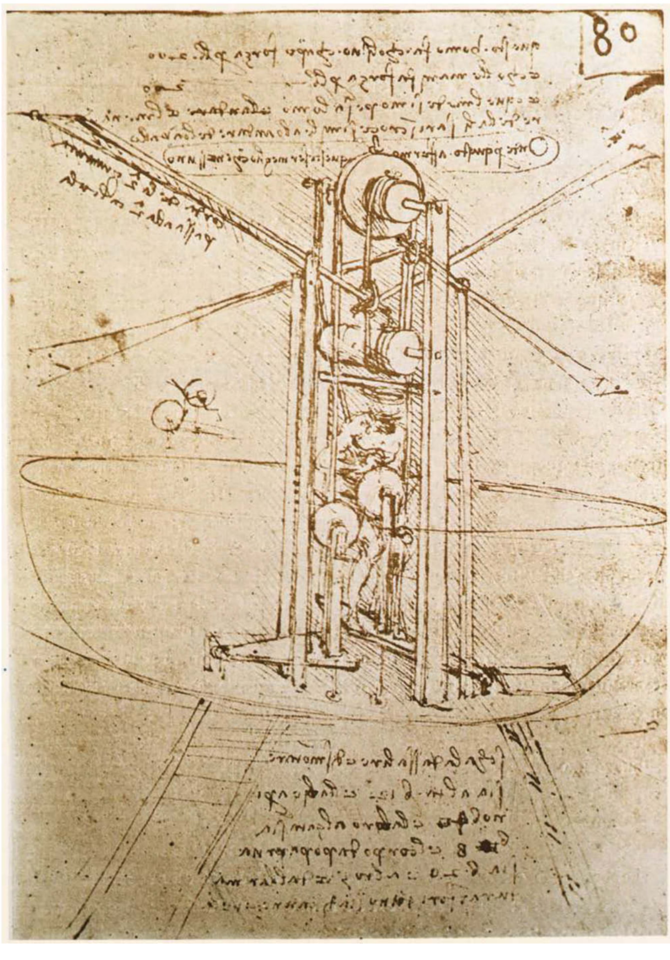

Figure 1.21 Da Vinci's Flying Machine Illustration. (By Leonardo da Vinci, Public Domain, https://commons.wikimedia.org/w/index.php?curid=11228914.)

or solar thermal energy, onto a small area. He drafted thoughts about an adding machine and a double ship hull. Although Da Vinci was an enthusiastic, visionary and productive designer, few of his designs were constructed or even feasible during his lifetime. The reason is that the current advances in manufacturing, metallurgy, construction, and mechanical engineering were not known during his time to materialize his thoughts.

Other significant scientific advances during the renaissance time were made by Galileo Galilei (1564–1642) in astronomy, kinematics, dynamics, physics, engineering, and mathematics.

Also, Tycho Brahe (1546–1601) had significant contribution in astronomy and inventions of accurate instruments of measurement. Meanwhile, Johannes Kepler (1571–1630) discovered the popular laws of orbital and planetary motion. Other examples would include Copernicus (1473–1543), who revolutionary theorized that the Earth moved around the Sun and not the opposite paving the way to real scientific thinking, which consequently led to aeronautical engineering as we know it today.

Another important development was in the process of discovery, focusing on empirical evidence and the importance of mathematics. An early and influential proponent of these ideas was Francis Bacon (1561–1626).

A major contribution to scientific theories, ideas, and logic thinking, which form the backbone of any engineering education, was the invention of printing and the printing press by Johannes Gutenberg (1400–1468). Such a milestone played a key role in the development of the Renaissance, Reformation, the Age of Enlightenment, and the Scientific Revolution.

Consequently, the development of the current engineering disciplines is based principally on that period's influences in physics, chemistry, and mathematics and their extensions into materials science, solid and fluid mechanics, thermodynamics, heat transfer and materials processing, and systems analysis.

1.12 Engineering and the Industrial Revolution

The Industrial Revolution is another landmark in the history of engineering. It is the process causing the dramatic change from a craft-based industry to the machine-based manufacturing. This process began in Britain in the 18th century and later spread to the rest of the world.

Among such technological transformation processes were the substitution of water, wind, human, and animal power by machine power. The invention of a developed version of the steam engine by James Watt (1736–1819), a Scottish mechanical engineer (shown in Figure 1.22), provided the means for progressive development in several different areas. One was the introduction of machines into the manufacturing

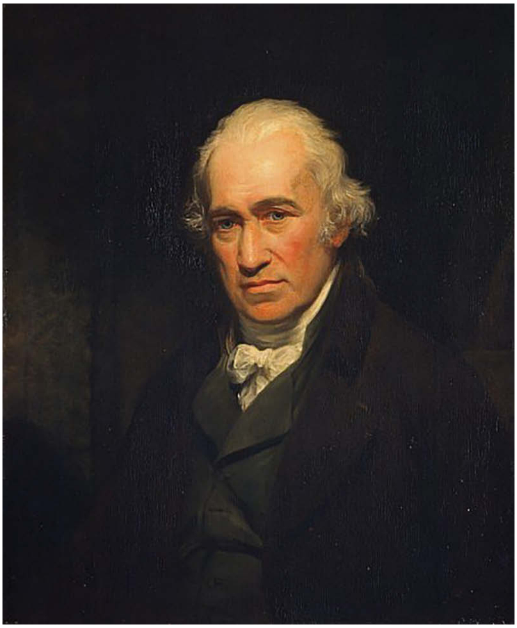

Figure 1.22 James Watt (1737–1819). (By John Partridge—https://www.national-galleries.org/collection/artists-a-z/b/artist/sir-william-beechey/object/james-watt-1736-1819-engineer-inventor-of-the-steam-engine-pg-2612, Public Domain, https://commons.wikimedia.org/w/index.php?curid=42586342.)

of textiles which was a primitive fabrication process, where people used to make clothes by working in their homes or in small groups. After the introduction of the steam engine, illustrated by James Watt in Figure 1.23, the cloth was made in large factories using machinery powered by steam engines. Thus, textiles engineering with its two major branches, namely the spinning and weaving industry, took place in England and the United States. Further, such complexity introduced the concept of the factory, the system, and the industrial organization to the world. This, in turn, had a dramatic impact on the economy, which led Adam Smith in (1776) to write his famous and fundamental book about "The Wealth of Nations" which restructures the bases for economic concepts and growth.

In addition, the steam engine transformed transportation in particular, the development of the steamship, and the steam locomotive greatly increased the speed with which people could move and increase the number of materials and goods that could be moved. For instance, the formulation above of classical economics by Adam Smith caused the

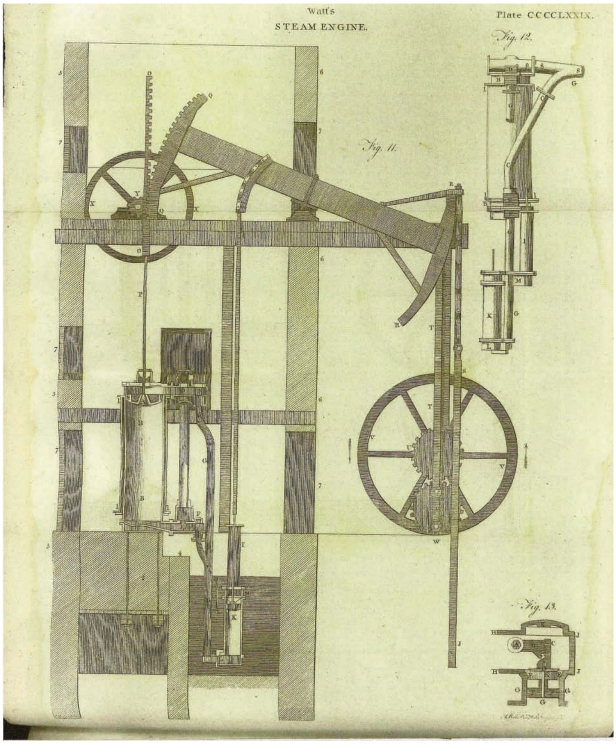

Figure 1.23 A drawing of James Watt's Steam Engine printed in the 3rd edition Britannica 1797. (By DigbyDalton—Encyclopædia Britannica Third Edition (Own work scan), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=33043116.)

belief in mercantilism theory of trade to decline. As a result, Britain used its steam-powered naval supremacy to consolidate foreign markets for the resources of the British colonies. The industrial revolution also involved the wide production and use of new basic materials like iron and steel.

Another main feature of the industrial revolution era was the socio-economic changes followed by the invention of telegraph developed between 1830 and 1840 by Samuel Morse (1791–1872) and other inventors; the telegraph revolutionized long-distance communication.

The industrial revolution witnessed the use of other energy sources, including coal, electricity, and petroleum. Along with many contributors during the same period, Samuel Brown, an English engineer and inventor, in 1823 patented the first internal combustion engine to be applied in industry.

These technological changes made possible a tremendously increased use of natural resources and the mass production of manufactured goods.

1.13 Napoleon 1 and the first school of engineering in Europe

One of the first engineering colleges in Europe was the polytechnic college *École Polytechnique* founded in 1794, in France during the times of the French Revolution. It was originally named *École Centrale des Travaux Publics*, Central School of Public Works. Its mission was to provide its students with a scientific background education with a strong emphasis in mathematics, physics, and chemistry, and to prepare them upon graduation to enter the national institutes of public works.

It should be noted that around 50 *École Polytechnique* students, along with a dozen professors and faculty members, accompany General Napoleon Bonaparte (later Emperor Napoleon I) on his expedition to Egypt on 1798–1801. Figure 1.24 shows Napoleon talking the group of scientists who accompanied him on the expedition. Many of their scientific remarks are included in the valuable Description of Egypt series of texts (*Description de l'Égypte*) which was published in 1809 (Figure 1.25).

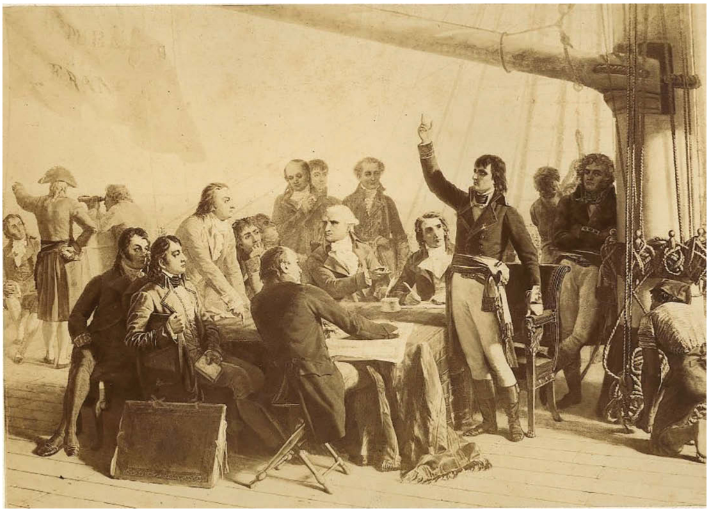

Figure 1.24 Napoleon Bonaparte talking with scientists on the way to the Egyptian expedition. (By Bingham, peintre anglais.—sabix.revues.org, Public Domain, https://commons.wikimedia.org/w/index.php?curid=38298719.)

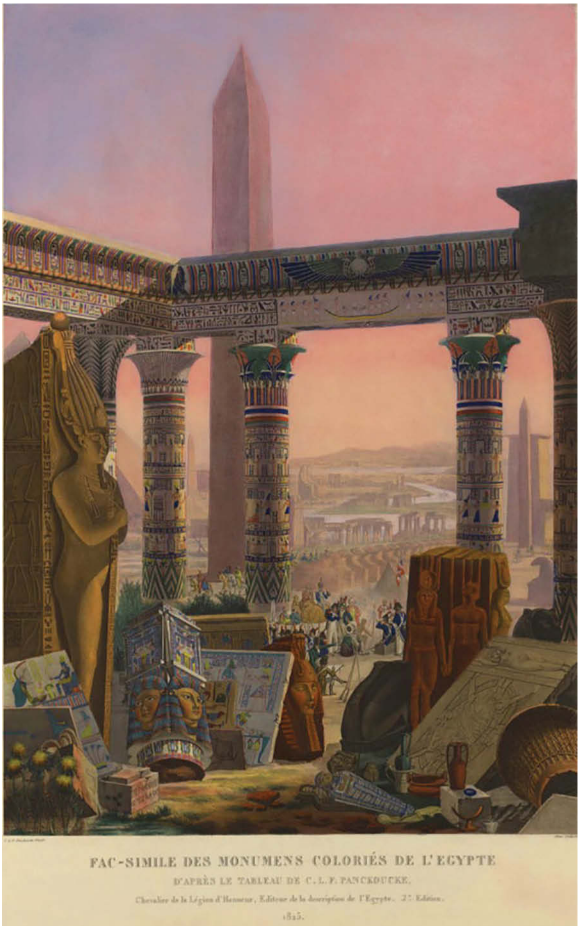

Figure 1.25 Frontispiece for the Description de l'Égypte, a work on Egypt commissioned by Napoleon. (By French Government—http://descegy.bibalex.org/Zoom.html?b=1&v=11&p=8&t=undefined, Public Domain, https://commons.wikimedia.org/w/index.php?curid=17723739.)

1.14 Historical universities offering engineering education

In this section, a quick preview of the oldest universities in the six continents that are still operating and currently encompass different models of academic engineering degrees is illustrated. It is important to remark that the following list is not a comprehensive one; nevertheless, it is intended to be a glimpse of the progress by which the engineering education evolved and witnessed in world history.

1.14.1 Europe

As already mentioned, European universities had its leading historical role in the world of science, arts, and engineering. The aforementioned analysis considered the ancient and the medieval era. It should also be noted that most of the old universities in Europe founded during that time were mainly devoted to, and still offering, studies in humanities, arts, medicine, and theological studies. However, there are other older universities in Europe which are still in operation and offering engineering degrees. The following is a list of a few of those oldest institutions, representing the premodern era, and ordered by the date of establishment.

Among the older European universities such as Paris, Oxford, and Cambridge, the University of Salamanca is a historic Spanish higher education institution, founded in 1218 in the city of Salamanca, west of Madrid. It is one of the oldest universities in the entire world still in operation. The University is currently offering undergraduate and graduate degrees in a number of engineering fields.

The University of Padua is an Italian university located in the city of Padua, Italy. The University of Padua was founded in 1222 as a school of law and was one of the most prominent universities in early modern Europe. The University of Padua is still in operation, and it has engineering education, undergraduate and graduate programs in industrial engineering, management engineering, information engineering, mechatronics, product innovation, and engineering of materials and nanostructures.

The University of Coimbra is a public university in Lisbon, Portugal, which was established in 1290. It is one of the oldest universities in continuous operation in the world, the oldest and the largest university of Portugal. The university is organized into several faculties granting academic bachelors, masters, and doctorate degrees in nearly all major fields of knowledge, including engineering and technologies.

Within the University of Coimbra, the Faculty of Sciences and Technology has 11 departments offering programs leading to the bachelor and graduate degree programs in design, multimedia, and geospatial information engineering.

Founded in 1592, the University of Dublin is Ireland's oldest operating university. It was modeled after the collegiate universities of Oxford and Cambridge, but unlike these only one college was established; as such, the designations "Trinity College" and "University of Dublin" are usually synonymous. The University of Dublin is one of the ancient universities of Britain and Ireland which is still in operation. Under the school of engineering, the university offers undergraduate and postgraduate programs in civil, structural and environmental engineering, electronic and electrical engineering, and mechanical and manufacturing engineering.

The University of Glasgow is one of Scotland's four ancient universities (Edinburgh, Aberdeen, and St. Andrews). The university was founded in 1451 and is still in operation. A bachelor's of engineering (BEng) and master's of engineering (MEng) are among the main professional degrees awarded by the University of Glasgow.

1.14.2 Asia

In Japan, with its 721 Japanese universities, Ryukoku University (established in 1639) is the oldest. It is a private higher education institution located in the urban setting of the large city of Kyoto. The university offers courses and programs leading to bachelor's degrees in several areas of engineering. Although ranked as the first university in Japan, it was not before (1877) that the University of Tokyo was established.

The University of Santo Tomas is a private university in Manila, Philippines. It was founded in 1611 and is the oldest extant university in the country and in Asia. The university is currently composed of several autonomous faculties, colleges, schools, and institutes, each conferring undergraduate and postgraduate degrees, and the basic education units. In 1907, the Faculty of Engineering was founded. Currently, it offers a bachelor's of science in chemical engineering, civil engineering, electrical engineering, electronics, industrial engineering, mechanical engineering, and communications engineering.

The foundation of Sungkyunkwan University, South Korea dates back to 1398 which makes it the oldest in Asia. However, since its establishment, it was mainly devoted to natural sciences and humanities. A graduate school of mobile systems engineering, sponsored by Samsung Electronics, was established in 2006.

Other Asian universities currently offering engineering curricula were founded back in the 19th century, for instance, the University of Indonesia, Indonesia (1849), and University of Calcutta and University of Mumbai, India (both in 1857).

Extended mostly in Asia and Europe, Russia, with its 379 universities, is listed here. St. Petersburg State University is the oldest Russian university (founded in 1724 by Peter the Great). It is a public higher education institution located in the city of Saint Petersburg, Russian Federation. This university has currently an enrollment of about 25,000 students. The university offers courses and programs leading to bachelor degrees in several areas of engineering studies.

In China, with its 861 Chinese universities, Wuhan University (established in 1893) is a public higher education institution located in Wuhan, People's Republic of China. Wuhan University has currently an enrollment of over 45,000 students. The university offers courses and programs leading to higher education degrees such as bachelor degrees in several areas engineering studies.

1.14.3 North America

Harvard University was founded in 1636, and it was named Harvard College in 1639, chartered in 1650. It is the oldest institution of higher education in the United States. It was officially recognized as a university by the Massachusetts Constitution of 1780. The engineering school within Harvard University's Faculty of Arts and Sciences initially launched in 1847. Presently, it offers undergraduate and graduate degrees in engineering and applied sciences.

The U.S. Congress authorized the creation of the post of chief engineer and the corps of engineers for the army in 1775. The engineers were responsible for building fortifications, surveying terrain, and clearing roads during the independence war and they proved to be so valuable to the revolutionary forces.

Established in 1785, University of New Brunswick (UNB) is a higher education institution which is located in Fredericton town, Canada. UNB has currently an enrollment of around 15,000 students. It offers undergraduate programs in several engineering specializations.

Rensselaer Polytechnic Institute was established in 1824 for the "application of science to the common purposes of life" and is described as the oldest technological university in the English-speaking world. Numerous American colleges or departments of applied sciences were modeled after Rensselaer. During the second half of the 19th century, several universities were established all over the USA and Canada with majors basically in mechanical and civil engineering.

1.14.4 Africa

Even though early engineering evidences could be traced back and contributed to Africa, it was not until the 19th century to witness true engineering education in the continent. Mohamed Aly Pasha (1805–1949), ruler of Egypt, was convinced that modern western education was essential to establish a flourishing and powerful state. Thus, the beginning of modern engineering education in Egypt dates back to 1816 when he established "Madrasat El-Mohandeskhana" (School of Engineering). In 1858, a school for irrigation works at the Barrage and a school for the building were established.

Cairo University, which was established in 1908 as the oldest university in Africa, holds the traces of such schools in its current college of engineering. Mohamed Aly also conducted a series of missionaries for Egyptian students to western schools, mainly to France and some other European countries.

The result was a group of engineers specialized mainly in civil, architecture, mechanical, and manufacturing. Mohamed Mazhar, Aly Mubarak, and many others who were high caliber engineers educated in Europe and participated in modern engineering projects during their times.

Other old institutions in Africa include Fourah Bay College, which is currently a public university in Freetown, Sierra Leone and was originally founded in 1827 as an Anglican missionary school. It is considered the oldest university and the first western-style university built in West Africa. Currently, the college contains a faculty of engineering. University of Cape Town, South Africa was also initiated early in 1829, as a school for boys, which makes it the oldest extant university in Sub-Saharan Africa. The university presently constitutes a faculty of engineering among its affiliated colleges.

There are other old historical universities in Africa, Al-Azhar University, Cairo (established in 975), the University of Al Quaraouiyine (founded in 859 AD) in Morocco, which sometimes considered being the oldest existing, and continually operating educational institution in the world, and the University of Ez-Zitouna in Tunisia (established in 1300). Except for Al-Azhar University which currently incorporates a faculty of engineering (founded in 1961), the other two universities started and continued to be representatives of Islamic religious schools.

1.14.5 Oceania

Established in 1850, the University of Sydney is the oldest institution of its kind in Australia. It is a nonprofit public higher education institution located in the urban setting of the large city of Sydney, New South Wales, Australia. The University of Sydney is officially accredited by the Department of Education and Training, Australia. Currently, it has an enrollment of over 45,000 students. The University of Sydney offers engineering courses and programs leading to bachelor's degrees, master's degrees, and doctorate degrees in several areas of study. These areas include aeronautical engineering, agricultural engineering, architectural engineering, biomedical engineering, chemical engineering, civil and environmental engineering, computer and it engineering, electronic and electrical engineering, general engineering, geological engineering, industrial engineering, mechanical/manufacturing engineering, mining, and metallurgical engineering, and other engineering studies.

1.14.6 Latin America

The National University of San Marcos is a public university in Lima, Peru. It is the first officially established (chartered in 1551) and the longest continuously operating university in the Americas. The University of San Marcos has 60 academic-professional schools, organized into 20 faculties, and 6 academic areas. The university comprises a faculty of engineering which offers degrees in geological, mineral, civil and metallurgical engineering, systems and information engineering, agro-industrial engineering, electronics, electrical and telecommunications engineering, and industrial and textile engineering.

1.15 Epilogue: Engineering is the soul and mind of progress

Throughout this chapter, we took the reader through a journey of time, some thousands of years ago, following evidence of engineering education and application. Presenting landmarks from all over the world, whether these landmarks still exist or only ruins of it is what remains today, it proves that proper engineering principles were applied, and some education of these principles must have been in place, even if schools, colleges, or universities did not exist at that time. Then several contributors to maths and sciences, which are closely related to engineering, at different ages and from different countries were presented. Finally, universities around the globe that included engineering or still offering engineering programs were presented highlighting the different programs offered by these universities.

To conclude, engineering is truly a major contributor to the developing and even existence of mankind. Without engineering and its proper education, man would have not adapted to changes in nature or make use of the resources needed for humanity to develop and prosper.

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