ENGINEERS, MATHEMATICS AND LOGIC

by

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Engineers are justly proud of their profession being deeply rooted in mathematics, and that other professions are seeking to emulate them in the adoption of mathematical methods. But, pride has its pitfalls, and one of these is created by the belief that the ability to use mathematical methods makes engineers a logical and exclusive breed. The belief is largely harmless, but the expression of such superiority, in the Sri Lankan context, is reinforcing the barriers isolating the professional engineer from society, expediting the decline of the profession itself and making it virtually impossible for this august institution to regain its lost preeminence. It needs must be challenged, therefore.

A historical perspective will help clarify the changing interdependence, of the disciplines of engineering, logic and mathematics. Such historical landmarks as the first dam across the Nile, and the earliest writings on logic and mathematics provide good starting points for pinpointing the changes.

It is generally agreed that the first dam across the Nile was built by Manes around 3000 BC, 5000 years ago. Archeological evidence also shows that the canal system in the Euphrates-Tigris valley, the irrigation works in China, and the water supply and waste disposal system in Mojendadaro were contemporaneous with the dam across the Nile. These civil engineering works are quite comparable in size and complexity to those of today. They were no doubt the result of man's ability to observe nature; try out or experiment on nature's methods with a view to achieving his own ends; and his willingness to discard unsatisfactory methods and improve on the successful ones. This ability it is said, is seen even in the stone tools made by early man - the hominoid - about 2,000,000 years ago, long before the appearance of Homo Sapiens.

The earliest mathematical work,'The Elements' was written by Euclid (330-275 BC). It covered what was known of geometry at the time. 'Geometry' meant the measurement of the earth in Greek. It had been developed as a field science by the Egyptians, who were forced into measuring and marking out individual fields after each, more or less annual, flooding of the Nile. Ancient peoples had also developed methods of computation that enabled them to predict eclipses, demarcate the seasons, crisscross the Mediterranean, keep records of harvests, trade etc -- several centuries before Euclid. Cuneiform tablets unearthed in Babylonia and the manuscript written by the scribe Ahmes (a papyrus in the Rhind collection at the British Museum) provide testimony of these early developments. It is necessary to emphasize though that even these beginnings of mathematics were a millennia and more after the major engineering artifacts, such as the dam and the irrigation systems mentioned, had been created. It is also necessary to point out that mathematics evolved out of the need to solve practical problems in engineering, agriculture, trade, etc. Mathematics did not underpin engineering till after Newton.

The first treatise on logic is said to have been written by Aristotle (384-322 BC). Euclid used the rules of logic, formulated by Aristotle, in developing his geometry, and these rules continue to be used in mathematics since then. It is worth noting that Aristotle wrote on a wide range of subjects, and though nearly all his works have been lost, his ideas dominated the minds of men for 2 millennia -- till Newton (1642-1727).

The publication of Newton's 'Principia' in 1687, is often taken as demarcating the change, from ancient technology and associated scientific ideas to modern science and technology. Another development of this era, an all important one, was the calculus. Who first invented it, Leibniz or Newton, was a matter of dispute between the French and the English! Both of them seem to have thought it out, independent of each other. The credit for the convenient notation used today must, however, clearly go to Leibniz. Thus, the use of mathematical methods in engineering is, at best, only about 300 years old, whilst engineering as an identifiable human activity is at least 5 000 years old!

It is significant to note in this context, that in 1828 civil engineers defined engineering as the

> "art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states, both for external and

internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation, and docks for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters and light houses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and adoption of machinery, and in the drainage of cities and towns."

Civil engineers were apparently quite content to call their activity an art. Moreover, they seem to have thought it necessary to portray themselves as persons dedicated to purely social objectives including trade and commerce, and to serve their fellow men collectively, not individually as other professions such as law and medicine did and do.

The publication, by A N Whitehead (1861-1947) and Bertrand Russell (1872-1970) in the early years of this century, of the 'Principia Mathematica' which sought to derive all of mathematics from logic alone has had the effect of making even scientifically knowledgeable people believe that there is nothing more to mathematics than logic. Henri Poincar'e (1854-1912), one of the

greatest mathematicians of all time, whom E T Bell, in his 'Men of Mathematics', calls the 'last universalist', commented as follows about the attempt to identify mathematics with logic:

"If all the propositions that mathematicians enunciate can be deducted one from the other by the rules of formal logic, why is not mathematics reduced to an immense tautology? The syllogism can teach us nothing that is essentially new, and, if everything is to spring from the principle of identity, everything should be capable of being reduced to it. Shall we then admit that the theorems that fill so many volumes are nothing but devious ways of saying that A is A?"

Obviously, the subject is profound and there is much more to it than the sketchy statements given above. Further, besides deduction which is what 'being logical' is usually all about, there is induction in logic. Though many theorems in mathematics cannot be proved without induction, several mathematicians doubt its validity. A few extracts from 'Mathematics and Logic' by Mark Kac and Stanislaw Ulam, published after the debate on logic being the essence of mathematics had ended, should help engineers break out from the constraints of logic as mathematicians have done!

"Mathematics has been described as the science of drawing necessary conclusions. But, which conclusions? A mere chain of syllogisms is not mathematics. Somehow we choose statements that concisely embrace a large class of special cases and consider some proofs to be elegant or beautiful. There is thus more to the method than to the mere logic involved in deduction."

".... there is more to pure mathematics than is contained in Bertrand Russell's definition that; 'Pure mathematics is the class of all propositions of the form "p implies q", where p and q are propositions containing one or more variables, the same in the two propositions, and neither p nor q contains any constants except logical constants'."

"We shall not undertake to define mathematics, because to do so would be to circumscribe its domain."

"Mathematics is a self-contained microcosm, but it also has the potentiality of mirroring and modelling all the processes of thought and perhaps all of science. It has always had, and continues to an ever increasing degree to have, great usefulness. One could even go so far as to say that mathematics was necessary ..... for the development of the human race through the shaping of its modes of thinking"

The purpose of this article was not merely to expunge from the minds of engineers the idea, that being logical is paramount, and that inaction is preferable where there is a risk of seeming illogical. Engineers are creators, not mere thinkers. Logic and mathematics are presently the thinking tools of the engineer. Engineers have other tools too for measuring, for carrying out hard labour etc. All these are the means to their main task, the task of creating, adopting, constructing, renovating etc. And what they do should serve social ends, as the definition set out above has spelt out. Further, when the definition was laid down there were only two disciplines, civil engineering and military engineering, now there are so many that it would be difficult to list them all; and still others, vital to human life, are emerging such as agricultural and environmental engineering which we are unable to quite define today. But of this we can be certain, that these new disciplines are so wide that they can be foreseen to have room for engineers of every one of the many fragmented branches of the engineering profession that exist and more!

However diverse, engineering has a unity. This has been well expressed by a well known biologist and broadcaster, Magnus Pyke, in his work the 'Boundaries of Science':

"Engineering is a characteristic modern activity in which a group of sciences taught separately can be seen in actual practice to be used together for a single

purpose. The fundamental studies upon which all branches of engineering depend are general science, particularly physics, mathematics, and chemistry, and sometimes biology as well."

He also says:

"For the purpose of our discussions, however, the point is that a group of sciences, which in our modern fashion we divide one from the other, are, in fact, linked in the practice of engineering, and must be used together by a proper engineer who needs to deal with the multifarious matters which arise when an engineering project is to be undertaken."

Magnus Pyke was involved in food technology, among other things, and seems to have had much contact with engineers and engineering, and his compliment to engineers is worth recording here as a final comment on what engineers are.

"It is not unreasonable, however, to repeat the boast of the engineers that their proper training fits them for high office in society since 'it encompasses the four essentials of handling men, money, methods, and materials'."