Knowledge Transfer and Perceptions of the Passage of Time

ICEE-2002 Keynote Address

by

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On each birthday of the Bishop who had founded the school, more than three centuries earlier, all pupils were required to be freshly washed, with clean shirts, and polished shoes; in this presentable condition, places were taken in the school assembly and order duly prevailed. In his last will and testament the Bishop's had endowed an annual lecture and stipulated that the title should be one of his much-favoured sayings - 'The End of Education is a Man, not a Book'. This recurring event, with its rather obvious title, was very tedious to each successive audience of restless schoolboys. Styles of presentation varied, but speaker after speaker had unimaginatively addressed the subject in ways which changed only imperceptibly as the years passed. Usually, the long-departed Bishop would be eulogised, the captive audience being told that the Bishop had been a clever man and possibly the wisest of his time; his knowledge had seemingly been boundless. The lecturer of the year would then deliver a homily which sought to cast light on the innermost truths of the title.

Information travelled slowly in the 17th century. Whenever new knowledge did arrive in a society, the most likely outcomes would be resistance, probably disbelief, and elapse of a long time before assimilation. Galileo died in January, 1642, one year before the birth of Isaac Newton, both noteworthy events which preceded the life-span of the Bishop; it seems reasonable to assume that our Bishop was unaware of much of the new knowledge then extant.

Historic record reinforces this last assumption; those newly-arrived theories and analyses of natural phenomena which have been contrary to established beliefs and religious canons have customarily been either ignored or denied. Such reactions may simply be deemed unfortunate for cases of genuinely-new knowledge, but become regrettable when true for old knowledge as well. Good examples of the latter come from what might well be called 'utilitarian mathematics', core knowledge of particular significance to engineers and scientists; passage to slowly-awakening Europe was very long.

On the Indian sub-continent, long before the Christian era, Hindu, Buddhist, and Jain priestly scholars developed a mode of numeration more extensive and arguably superior to those which had their origins in Mesopotamian, Egyptian, Chinese or Greco-Roman

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civilisations. This south-asiatic contribution to human culture, primarily promoted by intense interest in both astronomy and astrology, gave to the world both the decimal system and the fundamentals of algebra and trigonometry. Nowadays, ‘the decimal system’ is very familiar, with the consequence that the extraordinary quality of abstract thinking needed to establish it, and the cultural and philosophical traditions within which it was born and nurtured, are all easily overlooked. The decimal system took shape when nine named numerals, expressed in symbolic form, were combined with the concept of zero as a number, the whole being arranged in place-value order; the end result could be regarded as a symbiosis of counting methods with what is now regarded as mathematical manipulation. Moreover, this system was attuned to the unique capability developed by Indian mathematicians for dealing with high numbers, a capability which persists in today’s common language, as the use of ‘lakh’ ($=10^5$) and ‘crore’ ($=10^7$); for a further illustration, compare ‘myriad’ ($=10^4$), the highest number for which Greek society had a name, with the situation in India at the commencement of the first millennium of the Christian era, by which time Jain texts had recorded names for powers of ten as high as 10^{17}.

The Indian concept of ‘Shûnya’, and its subsequent elevation to the status of a number of value 'zero' ranks high in the list of human intellectual achievements. In Sanskrit, ‘shûnya’ expressed ‘void, ‘emptiness’, ‘absence’, or simply ‘vacuity’. Thus the number ‘701’, spoken as seven hundred and one, would be ‘eka.shûnya.sapta’ if written from right to left in ascending place order; the equivalent of the latter, in English, could be ‘one.emptiness.seven’.

This Indian achievement continued beyond what are now the normal manipulations of the decimal place-order system. The astronomically-orientated scholars, more often than not expressing mathematical operations in poetic forms, investigated the relationships of decimal numbers less than unity and greater than zero, square and cube roots, negative, and ‘unknown’ numbers. In the last case, a salient point was reached much later in the year 497 (CE), when the twenty-three years old Aryabhata produced a slender work primarily concerned with the decimal system, but which is also the first extant book in the world to deal with basic algebraic relationships; it was later known as the ‘*Aryabhatia*’. In accordance with his Vedic traditions, Aryabhata wrote in verse; an elementary example, given in free (English) verse, is :-

> ’’In the rule of three,
> multiply the fruit by the desire
> and divide by the measure.
> The result will be the fruit of the desire.’’

Thus a basic rule of manipulation in a linear equation is described, in that $x = bc/a$ whenever $a/b = c/x$; in the *Aryabhatia*, ‘the measure’, ‘the fruit’. ‘the desire’, and ‘the fruit of the desire’ correspond to a, b, c, and x, respectively.

Manipulation of the ‘unknowns’ developed to a stage where all basic algebraic rules had been formulated. One hundred and thirty years after the *Aryabhatia* first appeared, the mathematician Brahmagupta produced a work (the ‘*Brahmasphutasiddhanta*’) in which zero was defined as the result of subtracting a number, such as ‘n’, from itself, so that $[n – n] = 0$. Brahmagupta's description of this operation was - ‘‘when zero (Shûnya) is added to a number or subtracted from a number, the number remains unchanged, ……..’’;

the phrase he uses at the end of this sentence extends the statement to - ‘‘…… whereas a number multiplied by zero becomes zero.’’ Brahmagupta's work was definitive; in modern parlance he had produced a 'seminal text' and, moreover, done so in the seventh century of the Christian era.

In the seventh century and later, problems arose for the 'West' due to not having the number zero, and are neatly illustrated by the recent world-wide celebration of the ‘Millennium'.

Midnight on 31st December, 1999, was conveniently but erroneously hailed as the start of the new ‘Millennium’, *i.e*., the third millennium of the calendar established by Pope St. John I. This Pope’s concern was that the Christian world of his time, which corresponded mainly with the Roman Catholic communities of Europe, customarily dated events from what was held to be the foundation date of Rome. The Pope appointed a monk, Dionysius Exiguus, and commissioned him to define a more suitable system of dating. As Stephen Jay Gould has pointed out in his book on the Millennium, Dionysius Exiguus accepted the date of birth of Jesus as the 25th day of December of the year 753 *ab urbe condita* ('from the foundation of the city'), and recommended that dates and time should forthwith start from 1st January, 754 *ab urbe condita*. In the new system of dating, and in accordance with the Pope’s remit, this became the first day of ’the year of our Lord’ (*anno domini*), but because Dionysius Exiguus did not know about zero, the 1st January of 754 *ab urbe condita* became the 1st January of 1 *anno domini* (i.e., 1 AD). Due to this failure to start counting from t=0, as engineers might now do, this has the further and curious arithmetical consequence that Jesus automatically becomes one year and six days old (in the Christian calendar) from the moment of his birth !

Referring again to Brahmagupta's great work, all the necessary rules for algebra, including the ‘rule of signs’, were stipulated, but in a form which used the language and imagery of commerce and the market place. Thus ‘dhana‘ (= fortunes) is used to represent positive numbers, whereas ‘rina’ (= debts) were negative. The evidence for the birth of algebra is contained in Brahmagupta’s text produced in the year 628 AD; with the modern equivalents given in parentheses, two early and one later sample from Brahmagupta’s complete list of algebraic rules are: -

* Dhana’ minus zero is ‘dhana’, and ‘rina’ minus zero is ‘rina’
  [i.e., $a - 0 = a$, and $(-b) - 0 = (-b)$]

* The product of zero multiplied by either a 'dhana’ or a ‘rina’ is zero
  [i.e., $a.0 = 0$, and $(-b).0 = 0$]

* The product or the quotient of a ‘rina’ multiplied by a ‘dhana’ is a ‘rina’ [i.e., $(-b).a = (-c)$, or $(1/-b).a = (-d)$]

This was not all. When Hindu resurgence compelled the Buddhist monks to leave India, it is noteworthy that treasures carried by some of those who travelled northwards into and over the Himalayas included tabulations of Tangents, Co-tangents, Sines, and Versines.

The enormous Arab/Islamic expansion following the seventh century became the vehicle for both transmission and refinement of this eastern mathematical knowledge. The communities of the new empire ranged eastwards from Spain to the Indus valley, and from northern Caucasia to southern Egypt; trade, commerce, and cultural exchange were to extend over this vast area. Moreover, Arab sailors, traders and geographers were to find their way eastwards to the mainland of south Asia, and through the archipelagos as far as the Moluccas. The first (Umayyad) dynasty followed the capture of Damascus, an oasis city which by the time of arrival of the Arabs had already existed for a thousand years and was one of two major western terminals of the legendary 'Silk road'. Damascus was soon to fall to the power of Abu Ja'far Al-Mansur.

In 762 AD, Al-Mansur decided to build a new city, with better communications to the east, on the river Tigris at a site just north of the ruins of ancient Babylon; he named it 'Baghdad'. Baghdad was to become the focus of a glittering civilisation and, for half a millenium, was the world centre for trade, science, learning and political power. Three years before his death in 775 AD, and a decade after its foundation, al-Mansur adopted Baghdad as capital of the Abbassid dynasty. Three particular Caliphs, al-Mansur himself, Harun al-Rashid (of 'the Thousand and one Nights' fame), and al-Ma'mun were generous patrons of learned and cultural activities. Of these, al-Ma'mun is specially important. Firstly, he sent out plenipotentiaries to seek out manuscripts and other records of antiquity, thereafter arranging translation into Arabic. Thus by various routes, the works of Archimedes, Ptolemy, Plato, Aristotle, Galen, Euclid, etc., arrived to Baghdad from both the Mediterranean and other western cities, including Constantinople, whilst those of Brahmagupta, Aryabhata, other Vedic, Buddhist and Jain documents, and those of the Persian scholars came from the east. The second significant act of al-Ma'mun was to found the *Bayt al-Hikma* ('House of Learning') in Baghdad, which became the workplace of a range of gifted scholars.

Prominent amongst these savants was the mathematician, Mohammad ibn Musa al-Khwarizmi whose repronounced name gives us the modern word 'algorithm'. His achievements include the first formulation of the general solution of second-order quadratic equations, with discussion of the appearance of square roots of negative numbers.

From al-Khwarizmi's book ', *Kitab al-jabr wa al-muqabalah* (the Book of Integration and Equation), the word 'algebra' is derived. The *Kitab al-jabr* concisely described the decimal system and other Indian mathematical formulations. Eight hundred years ago, the ultimate vehicle for the spreading of knowledge in a generally-used language was in the form of a manuscript book, with the copies which were necessary before the days of printing. In the history of dissemination of mathematics in the 12th century, this was the outstanding contribution of Leonardo of Pisa, better known to history as Fibonacci, famous for the series (1,1, 2, 3, 5, 8, 13, 21, etc.) which bears his name and the most distinguished western mathematician of his time. Leonardo Fibonacci's education was abnormal in that he obtained much of it whilst his father was serving as a minor offical, probably a consul, in North Africa; he was fluent in Arabic, and the father also ensured a mathematical education for his son as a preparation for accountancy and commercial/business transactions.

Towards the end of the 12^{th} century Fibonacci, the great amateur mathematician , was working as a merchant in the Middle East, parts of North Africa, and Anatolia on behalf of commercial interests in Pisa and Florence. He is known to have been a purchaser of both raw material for dyestuffs, and Alum for 'fixing' dyes, both used by the emergent textile industry of Florence. It is not known how the *Kitab al-jabr* came into his hands, but this would certainly have been facilitated by his command of Arabic and having important politico-commercial credentials. As the translator of al-Khwarizmi's work, and the first publication of his own treatise (the *Liber abaci*, in Latin) in 1202, more than any other he is due the historic credit for bringing knowledge of both the decimal system and algebra from the Arab/Muslim world into Europe. In playing his part to transfer the useful concept of 'void/emptiness/vacuity' over the centuries, Fibonacci also made a linguistic contribution as consequence of his use of the arabic word 'Zephirum', from which both 'Zero' and 'Cipher' are derived.

With the *Liber abaci*, and the revised edition of 1228, his material became familiar to a specialist few but, far from being generally accepted it was treated with both official and unofficial hostility The merchant and governing classes of Europe had vested interests in various systems of accountancy and reckoning, all of which were vigorously defended and, for the most part, were professional 'closed shops'. The established Church was in doctrinal opposition to Islam, and contributed to the denial; extreme cases occurred of arithmetical innovators being burned at the stake for a combination of heresy and 'using the infidel numbers' ! Moreover, the intellectual fraternity of the time used Latin as their medium of international communication, and saw little advantage in changing the writing of, say, a number such as CXVII to become117, and they presumably disregarded the difficulties inherent in, say, multiplying CXVII by XVI. A further example of resistance to change can be seen five centuries later, in 1687, at a time when England was near to the start of its industrial revolution, when Isaac Newton wrote his *Principia* in Latin, still the language of science, and learning in general. Newton's seminal text did not appear in English-language translation until 1729, two years after his death !

Approximately 1,300 years elapsed before the decimal system reached Europe thanks to Fibonacci, and started on a long process towards acceptance and assimilation. The base date is somewhat arguable, but it is clear that the transmission time of algebra was significantly quicker than this - a mere seven centuries ! If the examples used in this paper are extreme, they nevertheless serve to illustrate that the rate of information transmission into Europe, from the east, was extremely small from antiquity through to, say, the Renaissance. As circumstances changed, the maverick magician, the conjuror of strange artefacts disappeared and was replaced by the engineer, the creator of useful items, in quantity if so required, and a true instigator of change in all respects. Society, as we like to say, would never be the same again. Change, and sometimes rate of change are amply demonstrated by the activities of ICEE, which manifestly plays a significant role in the transference of educational knowledge related to most of the engineering sub-disciplines. Acceleration indeed takes place in this context but, as everyone is aware, the outcome does not correlate internationally to a corresponding transfer of practice; frequently this is attributed to uneven, some would say 'grossly uneven', distribution of resources.

For purposes of comment, the criteria adopted here for classifying the material of ICEE-2002 differs from that necessarily used this year by the UMIST organisers for convenience of presentation in the various sessions. Although difficult to quantify, the material suggests some interesting trends. At 28% of the total submissions, a figure which is not exceptional, 'new methods and techniques' represented the largest category, and could readily be divided into two equal groups: -

1. Newer pedagogic and organisational methods.

2. New, specific methods dealing with simulation techniques and 'hands-on' education, in many cases arising from activity in rapidly changing technologies, e.g., robotics and nanotechnology.

If deemed appropriate, the first of the categories (1) above, might well be augmented by two others :-

3. 'Partnerships' and related collaborations have been emphasised at past ICEE meetings and, this time,10% of papers reported on such matters,

4. 'Best practice' material, including skills and curriculum innovation, plus valuable material on students' perceptions and motivations, contributed about 4%.

If 1, 3, and 4 are combined with 2, an overall total of 42%, or so, of material was contributed in an enlarged category of new methods and techniques, some devoted to particular circumstances. To this might well be added the keynote address given by Dr. Garcia, which dealt with new arrangements for higher education in Mexico.

Regarding the use of computers/communication linking and media use in general, it is noteworthy that the terminology has not settled down,and might be said to be in ’creation-phase’; examples include ‘e-University’, ‘e-learning’, and ‘web-based learning’ all of which seem to be in widespread and largely interchangeable use. Another example arises from discussion of what tended to be described as 'virtual' and even 'remote' labs, topics which had 10%, or so, of material devoted to them.

Industrial and interdisciplinary experiences of students, and the oft-quoted 'needs of industry' attracted around 7% of conference material. Neither industry-based disagreements on what constitute 'the needs of ‘industry', nor the academic/industry division of opinion regarding respective roles escapd mention; this seemingly is a persistent feature of all technical education conferences ! A UMIST example of the organisational complexity of Masters' degrees with modular components, which suit full-time students but are available for industry-based personnel also, was creatively described.

Allocation of credit to students for out-of-University industrial and work experience, an elusive topic which evades general solution, arose within issues of Accreditation and Assessment (8%). A Czech contribution of factors, largely non-academic, which inhibit the international movement of students was presented and discussed; in the light of contemporary practices of academic cooperation, this exposed several undesirable, and presently intractable, difficulties.

Two groups of submissions are in sharp contrast, with each of them attracting 8% of conference material. One topic is newly emergent and deals with ways in which

'Globalisation' is likely to affect engineering education. The other is far from new, and addresses the broad topic of 'Engineering Education in developing countries'. The adjective 'International' in ICEE underlies the relevance of each of these two categories but, from the poorer regions of the world, both the relatively low submission of papers and very low attendances at most of the ICEE venues hitherto chosen are very disturbing. The interest in 'Globalisation' is understandable but disproportionate, and it is the exploration of problems, as perceived by the less-well-placed and poorer regions of the worlwhich need more attention.

'Globalisation' is the most recent extension of the concept of freeing markets from arbitrary restrictions, whether national government imposed or not, so facilitating increased trade and consequently enhancing wealth generation. This proposition is eroded by the diverse complaints of poorer countries in that most of them depend for too great a degree on either supplying raw materials without much value added, and/or that their various manufacturers experience difficulties in accessing markets in the richer countries because of import barriers and subtle kinds of protectionism.

The merits and demerits of the 'Globalisation' arena of argument do not concern ICEE, but improvement of poor country education facilities is key agenda. Hitherto, participation in ICEE conferences has primarily been from the richer countries of the world, a situation obvious from this year's submissions and attendances. Awareness of this situation is far from new and has already attracted attention and discussion; resource limitations, as already mentioned above, have generally been identified as the obstacle to increased participation from poorer regions. This is indeed a barrier but, as the atom-splitting pioneer physicist, Professor Ernest Rutherford, is reputed to have said to his small group of graduate students "Gentlemen, we have no money – hence we must think." Although formidable, the problem is not intractable, and a start might well be made by ceasing to choose venues for ICEE on the basis of bids from enthusiasts and, instead, request venues directly.

There is ample scope for a some experimentation by ICEE, and two targets are obvious. The populations of China and the four countries of the Indian sub-continent together are rather more than one third of the human race, and each could well be subject to requests for conference venues (*e.g.*, Shanghai or Beijing in one case, and Bangalore as another), in the not-so-far future. This would provide a measure of easier access for many who are concerned with engineering education, but who would otherwise be excluded. Much of the present imbalance in ICEE participation would be redressed, positive educational developments in neglected sectors could be initiated, a fresh search for resources for enhancing international collaboration would probably be stimulated, and a contribution would undoubtedly be made towards collective self-efficacy and higher morale.

Further to the above, a small range of topics, which included the relationships of Society (usually discussed in the singular ?) with Technology, together with near-philosophical questions relating to the application and role of engineering, had an interesting but not very weighty place in the programme. It would indeed be a great pity, in future, if no-one thought fit to think about such matters, and to make their observations or analyses known in submissions to ICEE.

Not unrelated to topics mentioned immediately above, was discussion on the motivations of young people to become engineers, and the related topic of the perceptions of 'Society' towards engineers and engineering. Much alarm was expressed with the ‘fall in recruitment’, but it was noticeable that this complaint primarily came from representatives from the more affluent countries; in the poorer countries, parental aspirations of parents are significantly different and tend to be biased towards the relatively safe and secure professions of Law, Medicine, and Engineering. The merits of engineering as a creative activity, the excitement to be derived from its capability for organised approaches to the solution of difficult problems, the spreading of its principles and ideas into other disciplines and sub-disciplines (e.g., biological engineering, medical engineering), and its contribution both currently and historically to human culture, are all neglected messages, not least by the ICEE.

The 2002 Conference had a good response, dealt with a great deal of material and, judging by sessions attended by the writer, did so at a great rate. For the record, ICEE-2002 successfully registered many, if not most of the important changes which are currently occurring in engineering education. Manchester itself rose to the occasion, and the sunshine belied its reputation as a wet and dripping city; it has, after all, known, produced, and survived great changes itself since the VI Legion of the Roman army, 1900 years ago, established the fortification and settlement of *Mancunium*.

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