# Global, integrated engineering education: a curriculum for the 21st Century

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**Opening Address**

ABSTRACT: Among advanced professional degree programmes *engineering* is uniquely tailored to create technological leaders for tomorrow's technologically advanced and competitive global society. An integrated programme will draw upon courses across an array of disciplines, from the standard skills of engineering and technology, the physical and biological sciences, mathematics and the liberal arts. Additionally a contemporary programme should integrate invention, innovation and entrepreneurship into all phases of study. Such integration can nurture a learning environment conducive to the creativity that is essential to leadership in tomorrow's world of technological innovation and the management of technological enterprises. Moreover, it is essential for practical global awareness that the curriculum be collaborative and international. The newly established NYU branch campus in Abu Dhabi offers an example of such a progressive engineering programme.

## INTRODUCTION

The large question before us is simply …*How can engineering education meet effectively the conflicting set of needs and challenges of the 21st Century?* Although the large question may be easy to state, it is far from simple to put it into a straightforward operational plan. In these reflections two foci will be used to illustrate the general paradigm: the meteoric rise, especially in the technological arena, with global consequences, of China and India; a new global engineering curriculum opening to its first phase in Abu Dhabi. These two examples of current developments that have universal impact on engineering and engineering education in our day will be further specified under the general rubric of *responsibility* as it pertains to engineering's grand challenges.

Several presuppositions guide the reflections in this paper:

- Modern technology depends on multiple layers and types of collaboration.
- Often such collaborations are international and multicultural, involving especially India and China.
- China and India are becoming technological centres of gravity in the world of the 21st Century, but their practices depart in *cultural* ways from those familiar to the West.
- Various regions within Asia, often dominated by either China or India, have urgent economic incentive to develop collaborative technology clusters within their own sphere of influence.
- Many of the technology and engineering leaders in China and India received their professional training in the United States or Europe, creating a basis of understanding necessary for successful collaboration.
- This creates an opportunity for engineering and technology entrepreneurial firms in the West to participate in the economic rise of China and India and a new set of challenges for technological universities in the West. Engineers need to understand how their particular contribution, while different than pure innovation, is both essential and beneficial to creative techno-science.

What will engineers be required to do in the world of the near future, perhaps less than twenty years from now? How will technological advances change the role of engineers? How will the changing political and economic balance influence the engineering profession? What steps should engineering educators take in the face of these dynamic realities? A clue to this may be found in the United States National Academy of Engineering's list of *Engineering's Grand Challenges*:

1. Make solar energy economical;
2. Provide energy from fusion;
3. Develop carbon sequestration methods;
4. Manage the nitrogen cycle;

5. Provide access to clean water;
6. Restore and improve urban infrastructure;
7. Advance health informatics;
8. Engineer better medicines;
9. Reverse-engineer the brain;
10. Prevent nuclear terror;
11. Secure cyberspace;
12. Enhance virtual reality;
13. Advance personalised learning;
14. Engineer the tools of scientific discovery [1].

Each of the enumerated challenges posits three conditions: In the first place, engineering in any of the identified areas must necessarily be collaborative, not only across engineering and scientific disciplines, but in the fields of cultural studies, medicine, ethics, economics, and politics, and perhaps others. Secondly, the collaboration must be global and must engage with the rising participation of China and India. And thirdly, since these grand challenges represent genuine attempts to remake the world, it is imperative that an ethics of technological responsibility be envisaged that will garner trans-cultural and trans-generational acceptance. Each of the characteristics of technology development mentioned above is, to a large extent, modified by the practices that have resulted from globalisation. Collaborative interaction across geographic, political, cultural and economic borders poses serious questions concerning responsible practice with both ethical and legal dimensions. How the engineering profession responds is our special concern.

## RESPONSIBILITY

The ethical question, now as central to engineering as it has been to medicine, but perhaps even more difficult, will be framed around the notion of an imperative of responsibility. The concept of *responsibility*, especially in our global and technological era, can be an organising principle for an engineering curriculum. How can this be done? First let us examine the idea of responsibility, especially in the context of the emerging technologies, many of which are the means for approaching the grand challenges of engineering. For this it is helpful need to reflect on the traditional approaches in philosophy, ethics and the law to the question of responsibility. This discussion will follow in the footsteps of the pre-eminent philosopher of responsibility in our technological era, Hans Jonas.

Asking about the meaning of responsibility in the technologically shaped world of today, Hans Jonas proclaims:

> *…man is evermore the maker of what he has made and the doer of what he can do, and most of all the preparer of what he will be able to do next. But who is* he*? Not you or I: it is the aggregate, not the individual doer or deed that matters here; and the indefinite future, rather than the contemporary context of the action, constitutes the relevant horizon of responsibility. This requires imperatives of a new sort. If the realm of making has invaded the space of essential action, then morality must invade the realm of making, from which it has formerly stayed aloof, and must do so in the form of public policy. Public policy has never had to deal before with issues of such inclusiveness and such lengths of anticipation. In fact, the changed nature of human action changes the very nature of politics* [2].

Challenged by this apprehension, it may be valuable to examine the key elements of Jonas's position with particular reference to that most ubiquitous and, perhaps, most powerful of contemporary technologies, media technology, and in respect to the instruments of public policy, especially the law. What are the imperatives of responsibility in an era of media technology and the rule of law? It should be noted that for Jonas the rule of law is itself a moral imperative. But in his view, the rule of law is not now nor ever has been sufficient to guarantee responsible action. The current debates over regulation of the emerging medical and information technologies do not, for the most part, address the crucial questions of the responsible practice of these technologies, except within limited contexts.

Jonas has singled out media technology as one of the major phenomena separating the possibilities of 20$^{th}$ Century humanity from those available to the Greeks:

> *Immortal fame is thus public honor in perpetuity, as the body politic is human life in perpetuity. Now, already Aristotle pointed out that honor is worth just as much as the judgment of those who bestow it. But then, the desire for it, and a fortiori the desire for its extension into posthumous fame, and ultimately the estimation of this form of immortality in principle, are justified only by the trust we can reasonably place in the integrity of its trustee and master, namely, public opinion: in its enlightenment now, its faithfulness in the future - and, of course, in its own unceasing continuity, that is the indefinite survival of the commonwealth. Now on all these counts the modern temper cannot permit itself the innocent confidence of the Greeks. The selectiveness as such of this* immortality*: that it admits few and excludes most, we might accept if only we could believe in the justice of the selection. But for that we know too much of how reputations are made, how fame is fabricated, public opinion engineered, the record of history remade, and even premade, to the order of interest and power. In the age of the party line, and, for that matter, of Madison avenue, in the age of the universal corruption of the word, we are sadly aware that speech, the vehicle of this immortality, is the medium of lies*

*as well as of truth, and more often the former than the latter in the public sphere - with a busily fostered growth between them of unmeaningness, not even fit for either, eating away into both; and the older suspicion whether we are not dealing with a tale told by an idiot is overshadowed by the worse that it might be a tale concocted by knaves* [3].

What Jonas here refers to as the engineering of public opinion and the source of the universal corruption of the word is, in his view, invidious because it produces a specious form of immortal fame by debasing the primary vehicle of human action, i.e. speech. Both Pericles and Herodotus see speech and its preservation in history as ennobling. Pericles' lofty view in his Funeral Oration *...They received, each for his own memory, praise that will never die, and with it the grandest of all sepulchres, not that in which their mortal bones are laid, but a home in the minds of men, where their glory remains fresh to stir to speech or action as the occasion comes by…* [4] sets the standard of an abiding praise of the realisation of the good in human life and experience. This ideal celebrated by Pericles has not disappeared in our day. Jonas, for example, cites the self-declared motivation of an astronaut speaking in a TV interview to be nothing other than immortal fame; but such immortality, as it is known today, has been mass produced by media technology. Andy Warhol's prescient fifteen minutes of fame is now daily produced across all social strata by numerous word *technicians* prevalent in the mass media today.

In this context we should recall how Norbert Wiener defined for us the modern notion of *information*. Information, according to Jonas, forms together with *teleology* and *mind* the three-legged stool of cybernetics that technology, which claims most to grasp and emulate human behaviour. Wiener said *...Information is a name used to designate the continuity of that which is exchanged with the exterior world to the degree that we adapt ourselves there, and apply to ourselves the result of that adaptation* [5]. To live effectively is to live with adequate information. Thus, communication and regulation concern the essential part of the inner life of man, even as they concern his life in society. Although Jonas generally finds the claims of cybernetics *spurious and mainly verbal* he would agree with Wiener in this assessment of the formative power of technologically managed information on both the inner and public life of man.

The philosophical/political issue posed by Pericles in his oration upon the Athenian dead is the problem of law and justice as taken up in Plato's *Republic*. In a different vein than Jonas Karl Popper found incipient social engineering in Plato's approach to justice. For Popper, this kind of technology is to be feared because it denies basic liberties and foreshadows totalitarianism. Its mistake, Popper argues, is a specious account of natural and historical law. Popper is one with Jonas in the view that we cannot ordain the future, even for the sake of the good, and also in utter distrust of any form of utopianism. But Popper's recommendation of *piecemeal* engineering, while certainly an antidote to scientism and historicism, is for Jonas inadequate in that does nothing to insure that the legacy thereby left to the future is responsibly drafted. Indeed, it would do nothing to overthrow the narrowness and short-sightedness of Thrasymachean egoism.

Glaucon's interpretation of the Thrasymachean account of justice is supplemented by Adeimantus who sees the issue more explicitly in terms of opinion, which is, of course, formed by rhetoric (the art of Thrasymachos.) What most troubles Adeimantos is that justice is generally not praised for its own sake, but for its rewards. If justice itself is not good or pleasant, as Adeimantos allows the poetic tradition, as well as the laws teach, then what incentive is there for one to strive for justice? More to the point for Jonas is the reward structure itself. If justice is only praised for its rewards, then it can only be praised it terms of benefits understood and appreciated in the present. But just as children often do not appreciate the same rewards as their parents, the justice of today, if it is based on rewards, may have no bearing or a negative one on the future.

When Adeimantos objects to the conception of justice held by Thrasymachos, it is largely because he fears that Periclean like rewards and praise can be easily meted out without regard for true virtue. This is similar to the apprehensions of Jonas. The Socratic solution in the *Republic* is utopian; Jonas fears that the assent of technology takes utopianism beyond the status of philosophical dream to where it *appears to be capable of turning into a task, and Marxism has seized on this novel chance to give its political gospel eschatological exaltation and pragmatic credibility at the same time* [6].

As Jonas sees it, technology, and especially media or information technology, facilitates the rise of utopianism by simultaneously undermining the meaning of praise, distorting memory and reconfiguring the rule of law to conform with highly temporised intentionalities. The antidote to this situation is the moral virtue he calls responsibility, but it is precisely this virtue that he laments is so profoundly ill defined for the present age. Under such circumstances the development of moral virtues is confounded. The Aristotelian expectations of the reliability of *doxic exchange* and the function of the law as educator are both rendered false by the omnipresent engineering of public opinion.

Let us consider the possible limitations of the concept of responsibility as it is currently used both within and without legal discourse. Before examining the distinctions Jonas makes with regard to responsibility, the analysis of the eminent legal philosopher H.L.A. Hart will be indicated [7]. Hart classifies responsibility under four heads:

1. Role-Responsibility;
2. Causal-Responsibility;

3. Liability-Responsibility;
4. Capacity-Responsibility

Hart does not claim this classification to be exhaustive, but at least to identify the main types of responsibility to which reference is commonly made. However, Hart's categories all seem to fall under what Jonas denotes as Formal Responsibility.

All of the senses of responsibility noted by Hart are used to assign and clarify the appropriate, i.e. just, forms and degrees of accountability. For example, Benjamin Disraeli's role as British Prime Minister defines certain responsibilities as tasks, obligations inseparable from the job. To say that *Disraeli was responsible for the fall of the government* is (x) meaningful just in case some action of his can be related to the fall of the government in the same way as ice on the roadway can be related to an automobile accident. Whether or not he should be turned out of office is (y) another matter, one that has both legal and moral dimensions. Of course if illness or something else were to denature his very capacity to act, then his accountability for the actions is weakened. It is hard to see a single moral virtue central to any of these senses of responsibility. Rather it is the assignment of, and explanation for, proximate causation as relevant to praise and blame. Given the malleability of the body politic such determinations offer no beacon to guide human action.

It is this lack that concerns Jonas. The proliferation of tort litigation in the civil courts only testifies to this. That a plausible case to hold someone accountable can almost always be made is perhaps the clearest expression of the general lack of clarity regarding responsibility. Yet confusion on this level is not primarily what Jonas finds disturbing.

In his analysis of the various senses of responsibility Hans Jonas enumerates six types:

1. Formal Responsibility;
2. Substantive Responsibility;
3. Natural Responsibility;
4. Contractual Responsibility;
5. Political Responsibility;
6. Parental Responsibility.

In Jonas's view responsibility of any sort presupposes what he calls causal power, control by the agent and foreknowledge of the consequences. For the notion of responsibility to be at all meaningful, an agent must possess the power and control to carry out an act for which some consequences are anticipated. These are minima before responsibility can even be considered and, thus, are the formal conditions of responsibility. H.L.A. Hart, therefore, offers only an analysis of these conditions for the sake of fair accountability. Hans Jonas, on the other hand, is inquiring into what calls forth a sense of responsibility, i.e. what makes an action as such responsible. The problem is similar to that faced by Aristotle's *phronemos* in attempting the practical syllogism. However, Aristotle takes for granted the basic continuity of the body politic because the judgments pertain to the foreseeable future. The question Jonas pursues demands a practical wisdom about a future that will be radically different in large measure because of actions performed in the present.

About *Formal Responsibility* Jonas acknowledges it is the basis for praise and blame and legally the foundation for the important distinction between civil liability and criminal culpability. Civil liability presumes the ongoing responsibility of the agent whereas a criminal judgment asserts a failure of responsibility, which may require correction, deterrence and/or retribution. Justice, in demanding a fair accounting, posits an ideal world based on a reasonable assessment of the *status quo*. This standard cannot apply to a future different than the present unless the future can be prefigured (as in utopian solutions). Indeed utopianism is the tempting solution to the dilemma Jonas raises.

*Substantive Responsibility* is the category that includes actions that will make a difference for the future, both foreseeable and unforeseeable. This sort of responsibility can never be fulfilled by obedience to the law. Of course obedience to the law may insure that an individual's actions will not be found formally to violate the requirements of responsibility and Jonas, like Paul, Augustine and Kant, does not advocate disobedience. In fact, Jonas's respect for the law is central to the imperative of responsibility.

In an essay drafted in 1929, but not published until 1964 on the occasion of Rudolph Bultmann's 80$^{th}$ birthday anniversary, a philosophical meditation on the Seventh Chapter of Paul's *Epistle to the Romans*, Jonas develops his first thoughts on the practical and metaphysical necessity of law. Jonas's view is that each of us, i.e., universal, existential humanity and not the *massified* group engendered by technology, do not have the power to will the good; therefore the formal structure for the will which is the law is required. The reverence for the law, an attitude Jonas also notes in Kant, is not because the law itself is or could be sufficient; rather it is because it keeps us from full acquiescence to inclination, or what he refers to as the affectations of objective experience. In *The Imperative of Responsibility* Jonas summarises his own view of the limitations of law with reference to Kant:

> *While not denying that objects can affect us by their worth, [Kant] denies (for the sake of the* autonomy *of reason) that this emotive affection supplies the true motive for moral action; and while stressing the rational objectivity of a universal moral law, he concedes the necessary role of feeling in conforming to it. What is*

*unique is that this feeling is directed not at a material object but at the law itself. It was indeed among the profound insights of Kant, the more telling for coming from the champion of unadulterated autonomy of reason in moral matters, that besides reason there must also be sentiment at work so that the moral law can gain the force to affect our will. ...this sentiment [is] evoked in us ... by the idea of duty, that is, of the moral law itself; ...this sentiment was reverence* (Ehrfurcht) [8].

Of course it would be incorrect to treat law simply as the formal rational structure for emotive and affective experience. Law is present to us, as Pericles pointed out, in the way it is administered. The *logos* of law is the human instantiation of the metaphysical formality of law and is most evident in legal institutions such as courts of law. Jonas understands the operations of legal institutions teleologically, as fulfilling the ends that called them into existence in the first place.

Jonas asserts that the court of law was established in order to administer justice and justice is that *for which* it was created. That is to say the formal and final causes coincide and are immanent in the operation of the institution. *The will of the instituting power continues itself in the will of the institution, or else is perverted in it, or modified, enlarged, restricted ...it is true for the* court of law *...that a purpose is not only objectively its raison d'être but also subjectively the continued condition of its functioning, insofar as the members of the court must themselves have appropriated the purpose for the court to function as a court* [9]. Clearly, on this account, the subjective appropriation by the members of the court of the idea of justice is the *sine qua non* for the responsible administration of the law.

The subjective appropriation of the idea of justice has always depended on speech, whether words of praise and blame or the straightforward statement of the law. Whether one holds that our performance of just acts follows immediately from our knowledge of the just and the good, or requires the inculcation of habit, the institutions of justice are those of speech. Freedom of speech is more than a right to enjoy; it is the condition for the institutionalisation of justice.

What if speech is debased as Jonas suggests? Can speech be preserved in the era of information technology? Does the enormous power of modern media technology to shape opinion, present virtual realities, excite an ever changing panoply of economies of desire, and finally overwhelm us with the sheer volume of available information make the subjective appropriation of justice a humanly unattainable goal? And if this is so, what beacon guides us into the dark future?

In the end Hans Jonas's trenchant analysis of how technology shapes the life world and its institutions must leave us aware of our need for some redeeming insight. It is far too early to announce the end of philosophy.

Can technology undermine the power of language? Philosophy in the form of human wisdom, understanding and discernment depends upon the integrity of language. Does the law itself lose its power when language is manipulated? Is this process exaggerated when accelerated by the forces of technology? In a multicultural environment is it more likely that the standards for responsible action will be obscured? To consider this suite of overlapping questions, it will later be useful to allude to the dynamic example of India and China.

How can an engineering curriculum be organised? From the abstractness of philosophical reflection one turns to the practical issues of curricular organisation and development. Consider the following mission statement for a new international engineering programme:

*The Engineering major is built on the solid foundation of basic elements of liberal arts and the STEM Foundations Program. The major offers students the opportunity to explore $i^2e$ initiatives, working with teams with student colleagues from engineering and other majors, and in incubator initiatives. Students will be exposed to a series of engineering foundation courses, providing background in concepts relating to $i^2e$, engineering analysis and design, computation and simulation, and computer-aided design. Intermediate courses explore fundamental engineering topics of mechanics, thermodynamics, fluid mechanics, materials science, and electronic circuits. Students majoring in Engineering will receive a broad and in-depth education while acquiring working knowledge of trans-disciplinary technological fields covering civil, chemical, biological, computer, electrical or mechanical engineering* [10].

This is an admirably broad engineering programme that includes a substantial quotient of humanities and the liberal arts, project-based team learning experiences, incubator opportunities to foster entrepreneurial skills together with the fundamental science, technology, engineering and mathematics courses. It includes an imaginative capstone design course, as well as four-year sequence in ethics. And of course the entire programme is conducted in an international city by a university dedicated to global education. Is this approach sufficient on its own to ensure the meaningful integration of learning and the assimilation of both appropriate ethical values and the ability to think through the complex issues of global and future technology responsibility? Is not even this broadly conceived engineering curriculum short changing students with respect to these vital concerns?

The argument is often made that engineers need more exposure to the humanities. Engineering educators generally agree with this proposition but ask how this can be accomplished without weakening the already overloaded engineering curriculum. There is also the question of what instruction in the humanities is appropriate? The list of authors regarded as essential in Europe and the United States is unlikely to be accepted in other parts of the world. The

inclusion of the humanities in the globalisation of engineering education risks the reintroduction of a colonial or imperial mentality unless multi-cultural norms can be found. Engineering education faces incipient crises on two fronts: the pressure created by rapidly changing technology to include additional topics in the baccalaureate programme and the growing requirement for engineers to be able to make responsible cultural, political and social decisions that shape the future of the world. A simple curricular solution cannot address adequately these profound challenges. Rather, engineering and humanities educators need to form discursive alliances, based on mutual respect, that will enrich understanding and create the basis for meaningful deliberation.

The NYU-Polytechnic programme has the explicit advantage of being conceived as a global programme housed in a division of the university dedicated to an open and collaborative approach to cross cultural values. The success of this experiment in engineering education will depend, to a significant degree, upon how well the engineering school is integrated within the larger university community.

Currently engineering education exhibits two maladies. The first is within the domain of technical or engineering training narrowly defined and has to do with engineering skills *per se* and with their relationship to science and mathematics. In a sense, this is because engineering itself has become both more technical and less technical. There are many illustrations of this seemingly contradictory phenomenon. More and more engineering projects are extremely scientific and require deep knowledge of a variety of disciplines covering the full spectrum from biology to physics. The representation of the knowledge from these disciplines tends to be highly mathematical as mathematics is the language that permits discourse between biology and physics. But at the same time much of this is apparently simplified, made available, with an impressive degree of operational sophistication, even to those with a minimal grasp of the underlying processes by means of computer technology. Thus many very complex processes are masked by pleasing and rather simple computer interfaces. This creates an illusion of competence and one of the unpleasant tasks of engineering education is often to dissuade students of false presumptions of understanding.

Engineers, perhaps more than ever before, need to be scientists and competent applied mathematicians. This is to say that engineering rests upon complex theoretical ground and that innovative engineering research and practice needs to cultivate that ground. The problem for engineering education is that the demands of rigorous and contemporary science education are simply more than can be fit into an undergraduate engineering programme. Moreover, the mindsets of science and engineering, if not inimical, only share limited commonalities. Engineering students frequently articulate impatience with, and distaste for, their required science courses. This leads to the other side of the dilemma. If engineering students prefer practical, *hands-on* project-oriented, experiential learning while disdaining theory, the fact is that the majority enter engineering school with very little background for this kind of work. It is increasingly rare to meet students who have had much or any experience tinkering or repairing equipment. The students who have rebuilt a carburettor and put together a ham radio station are few and far between. In part, this is due to technological advancement and the ubiquitous presence of the microchip that makes it incredibly difficult or impossible to figure out how something works by carefully disassembling it and looking. The discovery of mechanical principles that could be achieved simply by taking an alarm clock apart is no longer an option found on every bedside table.

So this is the dilemma of engineering education. Students need more science and advanced mathematics in order to prepare for the sophisticated, advanced and innovative engineering work that will shape the future. The rigor and intensity of this kind of study is such that it cannot simply be added to the curriculum. Furthermore, it is not what most engineering students are well prepared to do or desire. On the other hand, what they do desire and what is also essential to engineering, *hands-on* experiential project-based learning is something most students have almost no background for. So the challenge engineering faculties' face, before being asked to improve their students' communications skills, leadership tendencies and project management acumen is already nearly overwhelming. Where, short of making the undergraduate degree a 5 or 6-year programme, is humanities education supposed to fit in?

The realistic answer is that it cannot. From the standpoint of the humanities, it is important to acknowledge this and imagine an honest strategy to address the loss. The adjective *honest* is used specifically. For the temptation will be, in order to save faculty lines and assuage accrediting agencies, to offer courses of instrumental value - perhaps something like technical writing - and claim that such instruction, without doubt valuable, provides all the humanities that engineers really need. If this kind of cosy relationship were to become normative, it would be a dishonest representation of the humanities and do a great disservice to both the engineering profession and the public at large, evermore in need of engineers whose human perspective is both long and broad.

The grand challenges of engineering are intended to address current or incipient crises of human kind; problems which are not originally engineering problems but which now urgently require the expertise that engineers can bring. But engineers need to explore new ground to understand the human foundations of these problems.

Much of the work of Amartya Sen has been directed toward exploring the kind of global economy that will not lead to the decline and often-serious deprivation of certain regions at the expense of growth and success in others [11].

These issues develop greater and more complex significance in the technologically-driven global environment. For some time there have been prognostications of the decline in influence of the nation state as a result of the ever-growing

power of multi-national corporations. Jean-Francois Lyotard's analysis of scientific knowledge as a kind of discourse connects this anticipated phenomenon with reference to the state of technology [12]. From an entirely different point of view, Keniche Ohmae has more recently argued that technology is the foundation for the new regional economies that have replaced the nation-state-driven economy [13]. As he sees it, the economic *challenges and opportunities* of the future are to be found in those regions of the world with innovative technological environments.

The majority of discussions of the future of India and China tend to abstract from their historical-cultural legacies and consider only the extent to which western models are successfully emulated [14]. As Yaheng Huang and Tarun Khann point out, there were two different paths to technological development following western precedents. *...China's export-led manufacturing boom is largely a creation of foreign direct investment, which effectively serves as a substitute for domestic entrepreneurship.* And *...India has managed to spawn a number of companies that now compete internationally ... many of these firms are in the most cutting-edge, knowledge-based industries* [15]. Such observations, while pointing to issues important to economic development anywhere, tend to be narrowly construed, taking too little account of the cultural environment that constitutes the arena for economic development and technological innovation. Careful consideration of such crucial topics as knowledge and human resources, educational policies, systems and institutions, including engineering education and technology development in China and India is also imperative [16][17]. In other words, the phenomena that Huang and Khann describe may be better approached if re-contextualised under the broad historical/philosophical categories suggested above.

## CONCLUSIONS

The conclusions are easy to state but difficult to carry out.

The challenges facing engineering education call for a new approach that goes well beyond what can be accomplished through curriculum reform. Engineering education needs to be particularly sensitive to the power inherent in technological solutions, power that may affect irreversible changes, changes to the environment obviously, but also social and cultural changes that will alter the very way life can be lived. Engineers are not accustomed to thinking about such things, except as private citizens. But the future calls for engineers to offer professional and, to the extent possible, scientifically validated approaches to the solutions of problems that have no specific engineering solution.

Engineering education's grand challenge is to prepare students to contribute to a world, which at present cannot be imagined fully, but which will be precarious more than it is currently, and most likely, in the words of Thomas Friedman *small, crowded and hot*. The key has to be good will collaboration with those whose traditions and values are unlikely to be our own.

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