AC 2010-1296: "BRIEF ENCOUNTER:" A REFLECTION ON WILLIAMS PROPOSALS FOR THE ENGINEERING CURRICULUM

John Heywood, Trinity College Dublin

Professorial Fellow Emeritius of Trinity COllege Dublin (Ireland. Formerly Professor of Education and Chair Department of Teacher Education.Has published over 50 papers on topics related to engineering and technological education and several books. His book "Engineering Education; Research and Development in Curriculum and Instruction" received the best reseach publication award of division i (professional) of the American Educational Research Association in 2005. previously he has been awarded a premium of the Education, Science and Technology division of the Institution of Electrical Engineers, and two gold medals and a silver medal from the Junior Institution of Engineers. In addition to a doctorate he has Masters degrees in engineering education, and letters. he is a fellow of the Chartered Management Institute

"Brief Encounter:" A Reflection on William's Proposals for the Engineering Curriculum

Abstract

In 2003 Rosalind Williams argued a case for a new approach to the engineering curriculum. She envisaged that there would be a convergence between technological and liberal arts education that would be "deep, long term and irreversible." Although her study seems to have had little general effect so far, its sentiments are to be found in important policy documents such as ABET 2000, the Carnegie Report on *Educating Engineers* and the National Academy's *Engineer 2020*. Given that educational proposals such as these have surfaced from time to time during the last century, in Britain as well as the US, it is appropriate to ask if they will be yet another "brief encounter" with the system as has been the fate of other educational innovations.

An account of Williams's thesis is related to recent US reports on the future of engineering education. Minor changes take place all the time and there are well-founded strategies for dealing with such change. Major change requires different strategies. Five factors that inhibit and enhance change are briefly considered. Any change that is envisaged has to take into account what many consider is an overloaded curriculum for this reason some form of integrated study is likely to be necessary. Some aspects of curriculum integration are considered and illustrated. It is argued that a liberal education (as defined) is more likely to be achieved through curriculum integration. While the principles are general, the particular responses of individuals and organizations to them will be dependent on the educational culture they inhabit.

Williams thesis and the case for curriculum reform

In 2002 Rosalind Williams published a book with the title *ReTooling*: *A Historian Confronts Technological Change.*[1] Her general thesis was accompanied by illustrations from the history of MIT, where as a social historian, she is Director of MIT's program in Science, Technology and Society. Subsequently in 2003 she published a short but controversial paper in *The Chronicle of Higher Education* with the intriguing title "Education for the profession formerly known as engineering." [2]

Williams argues that engineering has lost its identity because it "has evolved into an open-ended profession of everything in a world where technology shades into science, art, management with no strong institutions to define an overarching mission".

The consequence of this for engineering education is that there are numerous forces that pull engineering in different directions-"toward science, toward the market, toward design, toward systems and toward socialization". Within each specialization these demands are reflected in increasing demands on the curriculum. As Williams puts it each one adds a log to the curricula jams. Moreover, the trend to cram more and more into programmes "runs in exactly the wrong direction," and this is likely to reduce the number of students wanting to commit themselves to an education that is nearly all consuming" that is perceived to be very specialized.

One outcome of this increase in specialization is that serious debates have occurred that question whether or not certain subjects are engineering topics. Davis for example questioned whether or not 'software engineers' were engineers.[3] Williams argues that the future of engineering lies in accepting this multiplicity. She argues that engineering is expanding within its own walls rather than responding to the world outside. To accomplish this goal it will need a broader education that encompasses the liberal arts.

The author questions what would happen if matters continue as they are? One answer is that the number of technicians will grow considerably. Students will enter a particular route, graduate into the field and find there is no way out. They will become specialists. The consequences for employment are profound if the specialism dies. This was a prediction that was made as long ago as 1939 about developments in the UK by T. H. Marshall.[4]

At the present time consider the case of IBM which devotes a quarter of its R & D to developing a role in the service industries. Instead of hiring engineers to find out how such people as barbers, teachers, doctors, lawyers and others of a similar ilk think, it is hiring anthropologists, sociologists and economists to do that task.[5] One might ask- Why not philosophers? Be that as it may, there is a strong case to be made for a broader education to ensure that engineers can do just that. Indeed in the US Ec 2000 (ABET) demands that one of the outcomes of engineering education should be "a broad education necessary to understand the impact of engineering situations in global/societal context", and "knowledge of contemporary issues".[6] That the recent Carnegie Report should argue that understanding the engineers role in this way- "expands the dimensions of what is understood as core knowledge and competence for engineering programs", suggests that there is much to be done if the general thesis that " social science, and humanities have specific roles to play in the engineering curriculum"[7] is accepted. The Carnegie report regards them as key tools for understanding of engineering problem formulation, but also as a "necessary means for thinking about the place of the engineer in the new hybrid world".

The Engineer of 2020 (Part 1) from the National Academy of Engineering wants engineers to be leaders. This will not happen unless they are - "broadly educated, see themselves as global citizens, can lead in public service, as well as in research, development and design, are ethical and inclusive of all segments of society. The attributes include strong analytic skills, creativity, ingenuity, professionalism and leadership." [8] For the committee that produced the report the issue was - "how can we ensure that the engineering profession and engineering education adopt a collective vision including these aspirations and encouraging creation of an environment that promotes those attribute and aspirations in the future."[9] Williams and others argue that this cannot be accomplished without considerable curriculum reform.

As long ago as 1967 in the UK a report of the Council for Scientific Policy argued that scientists and technologists "must be aware of, and sensitive to, the boundary areas where their activity is felt; economic, social, humanitarian, organisational governmental. The longer their early studies can keep open this breadth of approach, the better." [10] Three years later the Confederation of British Industry was in discussion with one of the university matriculation boards about how such studies could be introduced into the examination for Engineering Science. During the same period some UK universities offered a course in the "Engineer and Society" which for some time was required for chartered membership of some of the institutions.

In the UK thirty years later, the then President of the Institution of Electrical Engineers E. J. Midwinter said of his approach to the curriculum that it was based on generalized systems and "It suggests common ground between engineering and most other disciplines. That engineering, science and law share common ground comes as no surprise but what about engineering and the liberal arts or the social sciences? Yet many of engineering's greatest failures have come from the failure to take into account the human dimension." [11]

While there may be common ground between engineering and law the two subjects approach "evidence" in different ways as American engineering educator Woodson made clear in his treatise on engineering design.[12] (See exhibit 1). To all intent and purpose they use different languages because they are different ways of thinking. Similarly the humanities and social sciences speak different languages. A liberal education helps one interpret these languages. But despite countless exhortations those responsible for engineering education continue to cram more and more into the pot. Evidently this is a feature that persisted throughout the twentieth century for in a report to the National Engineering Societies in 1918 Mann found that it (the curriculum) was "congested beyond endurance." [13]

Legal. Evidence that Mr A contracted to perform X for Mr B	**Nature of the evidence**	**Engineering** Evidence that a motor design A has a 10,000 –hr bearing life under given conditions*
The original contract itself	Proof inherent	Engineer witnesses tests; examines parts (being familiar with motors)*
A photocopy of the contract which is not immediately available	Proof available	Engineer reviews data of tests run by his employee.
X is being and has been regularly performed by Mr A for Mr B	Proof circumstantial	Motor design. Has been sold elsewhere for similar 10,000-hr duty
Expert testified that Mr A has accomplished X	Expert testimony	Consultant in motor field states he knows motor design A has passed 10,000-hr tests
Eyewitness Mr C testifies seeing Mr A perform	Eyewitness testimony	Non-expert, who observed tests at a distance reports the results.
Mr D testifies he heard Mr A performed X	Hearsay	Man on next project heard that motor design A passed

- The two situations are similar but not the same

Exhibit 1. T. T. Woodson's example of Evidence from Legal and Engineering Viewpoints. In Woodson, T. T. (1966) *Introduction to Engineering Design*. McGraw Hill, New York p 46.

Nevertheless, it is clear that there is not only a substantial case for curriculum reform along the lines promoted above but a widespread demand for it all levels of the engineering community. If, however, change is to endure then account needs to be taken on the one hand of the fact that enduring change of a radical nature is difficult to accomplish, and on the other hand that those who wish to induce change can be helped by theories of change.

The fleeting nature of change

A key question is "Will engineering educators be able to change the curriculum?" Viewed from the perspective of research on the curriculum in schools a cynic would posit the answer 'No.' In the United States a distinguished educator Larry Cuban had found that during the last 100 or more years most major innovations in school education had failed.[14] An example that is often cited is that of Dewey's democratic schools. The change that Williams and others are seeking is of that order of magnitude. Marzano and his colleagues have called this "second order". By first order they mean the small flow of minor changes that over time lead to revisions of the content of the particular subjects of the curriculum. This is happening all the time in engineering as a result of changing technology. It is one of the causes of the log-jam. Marzano has suggested that the reason why big changes have been difficult to implement is that the initiators have approached the problem with management strategies that only work for simple changes that are plausible and part of a continuing development.[15] For big changes different strategies are required. To understand what they are it is necessary to grasp how deep-seated our practices are in order to understand what it is that has to change.

First is the persistence of the curriculum. In the UK a distinguished commentator Simon Jenkins pointed out the irony of the great curriculum reform legislation of 1989 was that "a curriculum justified on economic and vocational grounds should turn out so traditional and unvocational in content."[…]"the subject bias was almost identical to that of the Secondary School (high school) regulations drawn up by Whitehall in 1904." [16] In the same vein the Carnegie report says that "much of undergraduate engineering education has remained the same since Jefferson's legislation establishing West Point although the emphasis given to the various components has shifted over time […][17]

Second is the persistence of certain forms of teaching. Cuban also showed how 'recitation' teaching in various forms has persisted. Yet it is clear that if a liberal education is to be achieved it will not be done so by attention to traditional methods of teaching and learning. Fortunately, in engineering education there is a small but seemingly significant movement for an evidence-based reform of teaching, notably in the US, that is seemingly having some effect.

Third is the role of faculty. There has to be a commitment to change on the part of all faculty if change is to become embedded. A point that has been illustrated in several reports of practice in engineering education. One in particular has illustrated the value of models of change in bringing about such commitment. For some this may require, for them at least, a perceived change in identity.[18]

Fourth is the persistence of identity that can be illustrated by a large change that took place in technological education in the UK in the nineteen-fifties. This was the introduction of compulsory liberal studies in the late middle nineteen fifties for students in the ten Colleges of Advanced Technology (CATs). Those studying for degree equivalent examinations (diplomas in technology) in engineering had to undertake three hours per week of liberal studies sometimes called general or complementary studies. This requirement was lost when these colleges became universities. At least one finding is relevant today. It was the quite simple observation that within the programmes offered by these colleges two kinds of subject (and approach) were offered. There were those subjects that had immediate relevance to engineering, as for example aspects of management, and there were those subjects that were distant from engineering as for example the history of art. The former subjects were called "tool" subjects and the latter "fringe" subjects. Student attitudes to these were as various as the students themselves but many students felt that such studies eroded their time studying engineering. Apart from that it would be difficult to argue that because students like or disliked liberal studies that this influenced their personal behaviour. Many of them had wide-ranging interests outside of formal education. But taken together were they liberally educated? [19] What is clear is that the provision of additional subjects whether "tool" or "fringe" is no guarantee of liberal education unless instruction and content are designed with the goals of liberal education in mind. If those goals are taken from such authorities as Arnold, Newman and Pattison then that means that there is a "cultivation of the intellect", and a focus on the person rather than engineering. The value to engineering follows: it is not a liberal education if it does not create the space for reflective thought through which a person can construct and reconstruct their identity. Inherent in Williams's view that engineering has lost its identity is the need to help engineering educators and their students reconstruct their identity. It is the fear of losing one's identity that is a major impediment to change. Changes in identity can only be brought about if a person internalises the new ideas and this can only be done if they are exposed to such ideas and given the opportunity to try them out. History shows that if ideas are constantly discussed they sometimes emerge in a form that guarantees their acceptance but not necessarily in the form the change agent might have wished.

Fifth, it is extremely difficult to persuade publishers to publish interdisciplinary texts for which initially the market is likely to be small.

Before presenting some ideas for bringing about this change it is necessary to make one further point about the practice of change that is often overlooked and that is the role of those in power. Very often those with the power authorise an individual(s) to make changes but do not subsequently give them the support they need. The respondents to change need to see that those with power support the change wholeheartedly and provide the resources for it to be brought about.[20]

Toward curriculum change

In general, therefore, curriculum change is more likely to be internalised when it is seen to be plausible, and planned to take place in small steps that are seen to be natural developments, one following from the other. Change should start from where the system and the personnel are at in knowledge and curriculum terms. There will be differences between national cultures. Without prior knowledge curriculum change will be difficult. Williams's idea that what is now called engineering education should be lowering the threshold of entry in order to mix with the larger world is probably outside the plausibility of those engaged in traditional courses. But several examples of service courses, particularly those that have a global dimension suggest that persons contributing to those courses would find Williams exhortation plausible.[21]

It is useful to have in mind the two distinctions that were made above. The first is between liberal studies and liberal education. The former is taken to mean the addition of subjects to the traditional engineering curriculum for the purpose of its broadening. Liberal education implies a broadening in which the mutual relationships between all the subjects of the curriculum are considered. It is, in the sense argued by Newman, Arnold and Pattison,[22] that it should lead to the enlargement of the mind or what today some would call the development of the whole person. Whereas *The Engineer 2020* requires attributes that include skill in analysis, creativity, ingenuity, professionalism and leadership. A liberal education also requires skill in synthesis, the ability to build bridges, and the attribute of reflective practice. The difference between liberal studies and liberal education will lie in the approach to learning and, therefore, teaching that is adopted.

The second distinction that was made was between "tool" and "fringe" liberal studies. Previous experience suggests that engineers may be more comfortable with an approach that is focussed on "tool" subjects that one that approaches the problem from the "fringe". Some subjects, can of course be either as for example philosophy. Taught from a historical perspective it is likely to be perceived as a "fringe" subject. Taught as a method that can be of use in engineering it is a "tool" subject.

The need for integration

The preceding argument is not to imply that the philosophy of liberal education is not relevant to "tool" subjects. On the contrary, because it would not be possible to teach all the "tool" subjects without hopelessly overloading the curriculum it will be necessary to provide some form of integration. The possibility of understanding the principle of mutual relations would seem to be better in an integrated program than in a traditional subject based curriculum. The key to creating that understanding and developing reflective practice will be in the techniques of assessment that are used and the backwash effect they have on teaching as well as learning. The model shown in exhibit 2 is intended to illustrate this fact and also to show what is possible in a short period of time. It is based on part of course that was developed for the Engineer in Society examination of the Council of Engineering Institutions in the UK. It was trialed with seventeen to eighteen year olds in a grammar school for the purpose of developing an 'A' (advanced) level examination of the General Certificate of Education.[23] This was at a time when the Confederation of British Industry was seeking the help of the examination board to support its Understanding British Industry project. Five-teaching hours were used for each of the six sections of the course both in the trial and the university programme from which the course was adapted. The course notes from the university were used. The terms in *italics* show some modifications that might be made to bring it up to date. In countries where university degrees are obtained from the study of a single subject (possibly two) for three or four years such as in Ireland similar criticisms of their lack of breadth may be made, and a subject such as this would achieve similar objectives. Subsequently the management and economic sections (sections 3 and 5) were developed as an integrated introduction to management for teachers in continuing professional development programmes and a specific text was published as an aid.[24] The theme of the text was adaptability in the face of change. It was treated with a focus on learning and learning organizations. In a long statement of objectives in addition to giving students an understanding of the problems of adaptation: the significance of values and beliefs in determining human behaviour there is lengthy statement of attitudes that the course was intended to foster which is given in exhibit 3.

Whatever the level at which this debate is considered, an integrated transdisciplinary approach is almost certainly inevitable.

A curriculum for building bridges

One way to develop a liberal education is to begin by building bridges within the engineering curriculum. A model designed to achieve this goal is shown in exhibit 4. The vertical axis represents the operations of the process of engineering, the horizontal axis, the resources used in those operations.

It is an adaptation of an earlier model developed by B. T. Turner in which the vegetation and animal cells were omitted from the resources.[25] The cells for man was not split between energy and ideas. The cells in the original were used to describe the key concepts of an aircraft ventilation system. Their purpose was to provide a synthesis of the knowledge required to design and manufacture artefacts of various kinds. An engineering course as conceived by this model would be based on problem and project base learning approaches. Case studies, problem-based activities and projects designed to cover the key concepts of engineering science and design. Application of the model necessarily illustrates Vincenti's point that engineering is a knowledge creating activity.[26] Engineering is a process of learning.

The modification shown here in exhibit 4 is due to a British engineer E. R. L. Lewis who was also a policymaker on educational matters for the electrical engineering industry. He used the model to show the elements of an integrated curriculum in engineering that took into account the social and humanitarian dimensions of engineering. Lewis who at the time was Chairman of a Regional Advisory Council for Technical Education also converted the model into a structure that took account of all the levels of further and technological education and he envisaged a curriculum for a College of Technology [polytechnic] in this way[27]. It is evident that an integrated programme of engineering studies can be developed in this way.

Proposed content (syllabus) areas for The Individual, Industry and Society taken from the minutes of a committee of the Joint Matriculation Board, Manchester, UK. circa 1973.

1. The individual, inventor and innovator
- notions of creativity, originality and the design process.
- the activities of engineering, industry and commerce (e.g. application, design, development, product, manufacturing- similar treatment for commercial institutions.
- the processes of innovation and invention; inventors and innovators.
- organization structures for effective innovation.
- value an economic growth.
-

2. The individual, society and technological change
- the Agricultural and Industrial revolutions.
- the characteristics of the Industrial revolution (causes and effects).
- changes in the social structure in England (using models of customary or status society, simple market societies and possessive market society); theories of social change: the role of institutions.
- interactions between technology and the individual; patterns of living and work; the price of labour, new resources (*sustainable energy*)

3. The individual and the economic and social environment
- location of British industry – role of the large and small firm
- concepts of wealth and economic growth; capital and interest; capitalism, countervailing power.
- the trade cycle (theories of Marx, Beveridge, Keynes and Galbraith); models of the market economy and the market economy with government intervention; the balance of payments; demand and cost inflation; *monetarism*.
- resources, waste, recovery.
- technology and pollution; the economy; the eco-system; voluntary change and/or legislation; conflicting views among scientists and economists about future economic growth.
- economic and social planning; the role of government.

4. The individual and the third world (*developing nations*)
- the process of development
- the difference between pre-industrial and industrial countries.
- market interactions between pre-industrial countries; trade involution.
- problem of aid; types of aid; moral issues.
- Intermediate technology.
- role of the small firm in creating entrepreneurs, capital and skilled labour.

5. Living with management

(a) The individual.
- theories of the person (social person, self-actualizing person, rational economic person, complex person, problem solving person).
- intelligence; distribution of intelligence among the population; *multiple intelligences;* ability, *aptitude* and work; personality and attitudes.
- problems of adaptation; principles of learning and perception; training and retraining.

(b) Organizations
- typical organization structures – line and functional roles.
- influence of technology on behaviour in organizations. Socio-technical systems.
- informal organization; the development of the human relations school of management theory.
- organizations as open and closed systems;
- packages (e.g. job enrichment, managerial grid, management by objectives)
- group technology.

(c) Responsibility and professionalism

6. Product and practice in the handling of projects
- product design for ease of manufacture
- standardisation; limits and tolerance
- design of production facilities; material handling and transport problems; organization for unit, mass and process production
- value engineering; project supervision; critical path planning
- costing; approaches to costing, balance sheets, income and expenditure statements.
- Simple statistical techniques
- Design of surveys, questionnaires etc., formulation of problems and evaluation and interpretation of data.

Exhibit 2

Development of attitudes in the proposed 'A' level-The Individual Industry and Society taken from the minutes of a committee of the Joint Matriculation Board, Manchester, UK circa 1973.

(a) Recognition that people act in accordance with their beliefs and results arise from action. Awareness that people do not necessarily perceive an object or situation in the same way.

(b) Recognition of the need for a method which organized, careful and intellectually honest in respect of circumstances of uncertainty.

(c) The acceptance of the need to consider parallel social and economic bases of technology and its role in the environment.

(d) An awareness of the advantage of seeking common ground to other fields to relate one kind of phenomenon to another.

(e) An awareness of the advantages and disadvantages of attempting to reduce a social, economic or scientific situations to a simple system.

(f) The recognition that it is necessary to exercise judgement as well as reason when dealing with problems.

(g) The recognition that a perfect answer to a problem may not exist and that the best available answer must often be sought in relation to the time available for its solution.

(h) The acceptance of the fact that more than one way of thinking exists and that different ways may be more appropriate to different problems or to different stages of the same problem.

(i) The recognition that the required of calculation may vary from time to time (for example from a preliminary, quick "order of magnitude" estimate to a precise forecast of performance)

(j) The recognition of the need to develop responsible attitudes and to individuals, *design*, society and work.

Exhibit 3.

0perations/resources	**Energy**	**Forces**	**Space**	**Materials**	**Vegetation**	**Animals**	**Man**	
							Energy	**Ideas**
Form and Properties	Solar Climatic	Gravity Electro-Mag. Inertial	Geometry	Solids Liquids Plasma	Trees Plants	Mammals Insects		Philosophy Aesthetics Politics
Availability (extraction)	Magnetic Hydrodynamic			Land Sea fuel	Food	Extinction	Athletics	Education
Measurement		Units	Astronomy	Geology	Growth		Efficiency of man//machine	Psychology/ Selection
Control (storage)	Hydraulic Pump storage		Space Research			Refrigeration		Sociology Management
Conversion	Nuclear Power			Manufacture	Silage	Cookery	Power Assisted controls	Thought
Transmission	Coal or Electricity DC/AC			Transport				Communication Language Design

Exhibit 4.

Matrices such as these may be designed to break down curriculum barriers but with the reduction in specialization they pose important problems for content and method. Principles have to be stated in such a way that the student understands them. Very often as is the case in mathematics "its elegance and logic" can only be appreciated by its use in other fields. Thus in so far as the example in exhibit 4 is concerned mathematics is a hidden bridge not merely between engineering and science but with the social sciences. The "what" of mathematics and "how" it should be taught remain contentious issues.

The design of assessment

Assessment is often criticised for the problems it creates rather than for the positive effect it can have on learning[28]. In the example below the essay assignment follows on classroom discussion that has considered how the usage of the "key concepts" varies as between different subjects. It was given to a group of second year students from the humanities who were taking an introductory course in physics for arts students who would otherwise not do any science at the university[29]. One of the goals of the course was "to enable the students to compare the structure of thought and methods of enquiry in physics with those of their own subject". It was hoped that the question set would stimulate them to consider this issue in some depth. The question for the assignment was:

Distinguish between the terms "mistake", "discrepancy", "uncertainty," "systematic error," and "random error" as applied to the experimental testing of a hypothesis. Compare the usefulness of the concept of error as used in physics with that of the errors occurring in the study of your major subject?

There are other key concepts that could be substituted in this question, as for example, "risk." Two concepts whose use in engineering may be elucidated by study of their use in other professional activities are "cause" and "correlation." For example, studies of the effectiveness of drugs, and in particular the Beta-Blocker experiments. Gage used these experimental results in his study of the problems of evaluating pedagogical techniques.[30] It is possible to show, as Woodson has done, the concepts of engineering science in an array from which an integrated programme in this area could be developed.[31]

Over and above assessment is learning. There is sporadic interest in helping students to learn but if reflective practice is to be meaningful then it has to involve meta-cognition and for this students have to learn about how they learn. It is through reflective practice that students not only learn the use of other dimensions of knowledge in the service of engineering, but the contribution they can make to a better understanding of themselves and the society in which they exist which is the greater purpose of a liberal education. Although the areas of knowledge covered in this model (exhibit 4) are limited there is also the possibility of extending the range to the crafts if some of the projects require the design and manufacture of an artefact. Or alternatively through concentrated courses of practice.[32]

Ability/competency integration

Other models of integration have been proposed and in particular are those that are based on ability/competency. At the high school level in the United States the SCANS model is particularly relevant.[33] The model is based on the idea that the graduates from high schools need to be competent in five areas. These are (1) *resources* so that the students know how to allocate time, money, materials, space and staff. (2) *interpersonal skills* so that students can work in teams, teach others, serve customers, lead, negotiate and work well with people in culturally diverse backgrounds. (3) *Information* so that students can acquire and evaluate data, organize and maintain files, interpret and communicate, and use computers to process information. (4) *Systems* so that students can understand social, organizational, and technological systems; they can monitor and correct performance; and they can design or improve systems. (5) *technology* so that students can select equipment and tools, apply technology to specific tasks, and maintain and troubleshoot equipment. The committee identified three foundation skills that competent workers in high performance workplaces need. These were (1) *Basic skills* in reading writing, arithmetic and mathematics, speaking and listening. (2) *Thinking skills* – the ability to learn, to reason, to think creatively, to make decisions, and to solve problems. (3) *Personal qualities* - individual responsibility, self-esteem and self-management, sociability and integrity. The committee argued that each subject of the school curriculum could contribute to the development of these competencies and presented matrices to demonstrate their point at any level K - 12. The problem with that approach is that the subjects of the curriculum may lose their integrity. If they don't the students may not be at a sufficient level of development (in Piagetian/Perry terms) to perceive what is expected of them

The limitations of the model derive from its focus on the workplace. It seeks to want the humanities and social studies to serve that aspect rather than that of showing the contribution they can make to liberal knowledge. Without the reflective component the Lewis model described above is open to the same criticism.

Many persons would be happy if the graduates of universities performed well in all these areas. The Employment Department[34] in England evidently thought so when it sponsored the Enterprise in Higher Education Initiative in universities in the UK around about the same time as SCANS. On the basis of complaints by employers to government that the products of universities were not suitable for work in industry and commerce because they lacked certain basic skills the Employment Department sponsored five-year projects in universities to develop programmes that incorporated these skills (exhibit 5). To get a five-year grant of $ 1.500, 000 a university had to commit all of its departments to the development of these skills within these programmes. This resulted in several major exercises in the humanities[35]. Against the belief that there should be no bolt-on courses it was argued that given the focus on interpersonal skills[36] that additional tuition should be provided in the human sciences. Of more significance, perhaps, was the argument that if the complaints of industrialists were taken at face value then what they were seeking was a liberal education. Both these points of view are contained in a report that was intended to provide a philosophy of enterprise learning.[37]

At university level Alverno College in Milwaukee has also shown how an ability-led programme leads through assessment to integration.[38] The curriculum focuses on eight abilities or competencies which have a strong "value" dimension. The abilities are (1) effective communication ability. (2) Analytical capability. (3) Problem solving ability. (4) Valuing in a decision making context. (5) Effective social interaction. (6) Taking responsibility for the global environment. (7) Effective citizenship. (8) Aesthetic responsiveness. Each subject area is required to contribute to the development of these abilities. The programme is of particular interest because it takes into account the needs of student development along the lines of the Perry model which together with the King and Kitchener model has excited some interest in engineering education.[39] Each ability is constructed of 6 sub-abilities that are hierarchically ordered. Over the whole programme of four years students are expected to attain level 4 in each of the abilities. Each subject specifies how it can contribute to the development of these abilities.

Each of these projects required a considerable change in the attitudes of teachers toward their teaching. Exhibit 6 is a comparison made by two engineers of traditional classrooms with those of public schools offering the SCANS programme in the Fort Worth District[40]. Evidence from publications about engineering education suggests that some progress is being made in changing the attitudes of engineering teachers to non-traditional modes of teaching.

Cognitive knowledge and skills

Knowledge:- Key concepts of enterprise learning (accounting, economics, organisational behaviour, inter and intra-personal behaviour.

Skills:-The ability to handle information, evaluate evidence, think critically, think systemically (in terms of systems), solve problems, argue rationally, and think creatively.

Social Skills, as for example the ability to communicate, and to work with others in a variety of roles both as leader and team member.

Managing one's self, as for example, to be able to take initiative, to act independently, to take reasoned risks, to want to achieve, to be willing to change, to be able to adapt, to be able to know one's self and one's values, and to be able to assess one's actions.

Learning to learn. To understand how one learns and solves problems in different contexts and to be able to apply the styles learnt appropriately in the solution of problems.

Exhibit 5. The four broad areas of learning together with the elements they comprise that are important for equipping students for their working lives, as defined by the REAL working group of the Employment Department's Enterprise in Higher Education Initiative**.**

Comment

Williams and others have called for engineering education to become more broadly based. If it does not then it will continue fractionalise and its members will be recognized for their mastery of the specialized technique and little else. There is no competition between the demand for training in the specialized technique, and the demand that engineers should receive a liberal education. However, the provision of additional isolated subjects will not achieve the goals that are required. Some form of integration is required. There are many ways of achieving integration[41]. It might be partially achieved by carefully designed problem-based learning, project-based learning, and case studies that function within a conceptual framework developed for this purpose. An example of such a framework was presented. The danger is that the focus will be on the service element of liberal studies at the expense of what these subjects give to liberal knowledge in their own right The development of skill in reflective thinking is therefore a major prerequisite of this approach to engineering education.[42] Other integrated approaches are possible. While the principles are general, the particular responses of individuals and organizations to them will be dependent on the educational culture(s) they inhabit.

Acknowledgements

I am grateful to the unknown reviewers and Ms Sarah Heywood for their constructive comments.

From the Conventional Classroom	**The SCANS Classroom**
Teacher knows answer	More than one solution may be viable and teacher may not have it in advance**.**
Students routinely work alone	Students routinely work with teachers, peers, and community members
Teacher plans all activities	Students and teachers plan and negotiate activities
Teacher makes all assessments. Information is organized, evaluated, interpreted and communicated to students by teacher	Students routinely assess themselves. Information is acquired, evaluated, organized, interpreted, and communicated by students to appropriate audiences.
Organizing system of the classroom in simple one teacher teaches 30 students.	Organizing systems are complex: teacher and students both reach out beyond school for additional information.
Reading, writing and math are treated as separate disciplines; listening and speaking often are missing from the curriculum.	Disciplines needed for problem solving are integrated; listening and speaking are fundamental parts of learning.
Thinking is usually "theoretical" and "academic"	Thinking involves problem solving, reasoning and decision making.
Students are expected to conform to teacher's behavioral expectations; integrity and honesty are monitored by teacher; students' self-esteem is often poor.	Students are expected to be responsible, sociable, self-managing, and resourceful; integrity and honesty are monitored within the social context of the classroom; students' self-esteem is high because they are in charge of own leaving.

Exhibit 6. The Conventional Classroom compared with the SCANS Classroom Cited by Christiano and Ramirez from Fort Worth Public Schools

Notes and references

1. Williams, R (2002) *Retooling. A Historian Confronts Technological Change*. MIT Press, Cambridge, MA.

2. Williams, R (2003) Education for the profession formerly known as engineering. *The Chronicle of Higher Education* issue January 24th.

3. Davis, M (1998) *Thinking like an Engineer. Studies in the Ethics of a Profession*. Oxford U.P p31 ff.

4 Marshall, T. H. (1939) Professionalism in relation to social structure and policy- reprinted in Marshall, T. H. (1963). *Sociology at the Crossroads and other Essays*. Heinemann, London
He writes: "there is another point. In the Church, the army, in law or in medicine a man at the head of his profession is on top of the world. He admits to no superiors. But many of these new semi-professions are really subordinate grades placed in the middle of the hierarchy of modern business organization. The educational ladder leads into them but there is no ladder leading out. The grade above is entered by a different road starting at a different level of the educational system. Social structure in so far as it reflects occupational structure is frozen as soon as it emerges from the fluid preparatory stage of schooling."

5 Heywood, J (2007) "Think…About How Others Think". Liberal education and engineering. Proceedings Frontiers in Education Conference (IEEE/ASEE) pp T3C-20 to 24.

6. ABET Ec 2000

7. Sheppard, S. D., Macatangay, K., Colby, A and W. M. Sullivan (2009) *Educating Engineers. Designing for the Future of the Field.* Carnegie Foundation. Jossey Bass, San Fransisco.

8. National Academy of Engineering (2004). *The Engineer of 2020. Visions of Engineering in the New Century.* Report of a Committee Part 1. National Academies Press, Washington DC.

9. *ibid* p 59.

10. Council for Scientific Policy (1967). *Enquiry into the flow of candidates in Science and Technology into Higher Education* (The Dainton report). HMSO, London.

11 Midwinter, E. J (2000) Something, old, something new and something just in time. Dilemmas for EE education and training. *Engineering, Science and Education Journal* October 9th (5), 219 – 230.

12 *Woodson,* T. T (1966) *An Introduction to Engineering Design*. McGraw Hill, New York

13. *loc.cit* ref 7. P 177.

14 Cuban, L (1987). Constancy and change in schools (1880's to the present) paper presented at a conference on restructuring education cited in P. W. Jackson (1993) *Handbook of Research in the Curriculum.* AERA/Macmillan, New York.

15 Marzano, R. J., Waters, T and B. A. McNulty (2005). *School Leadership that Works.* ASCD, Alexandria, VA

16. Jenkins, S (1995) *Accountable to None. The Tory Nationalization of Britain*. Hamish Hamilton, London. p 121

17. *loc.cit* ref 7 p 18

18 Heywood, J (2006) Factors in the adoption of change: identity, plausibility and power in promoting educational change. *Proceedings Frontiers in Education Conference* (IEEE/ASEE) ppT1B- 9 to 14.

19. For a review of research on liberal studies in the CAT's see Davies, L (1966) *Liberal Studies and Technology.* Wales University Press, Cardiff.

20. *loc. cit* ref 18.

21 See for example Mitcham, C and D. the Humanitarian context ch 9, and Part 5 Engineers in Civil Society of Christensen, S. H et al (eds) *Engineering in Context.* Academica Press, Denmark.

22. See for example Sparrow, J (1967) *Mark Pattison and the Idea of a University*. Cambridge University Press

23. The Joint Matriculation Board was one of five boards that set examinations for university entrance. It was owned by five universities. The government has since reorganised the organizational structure of the examining boards and they are now in the hands of private enterprise. The 'A' level examination at the time was generally considered to be the equivalent of first year and some second year courses in the USA. Professor Bucciarelli of MIT has inspected the 'A' level in engineering science papers and confirmed that view. The minutes referred to in the text are in the possession of this writer.

24. Heywood, J (1989) *Learning Adaptability and Change. The Challenge for Education and Industry*. Paul Chapman/Sage, London

25. In this paragraph the matrices designed by Turner and Lewis have been reproduced and discussed in Heywood, J (2005) *Engineering Education. Research and Development in Curriculum and Instruction.* IEEE/Wiley, NJ. P210 ff. Turner's matrices related to the design of an aircraft ventilation System

26. Vincenti, W. G (1990) *What Engineers Know and how they Know it. Analytical Studies from Aeronautical History.* The Johns Hopkins University Press, Baltimore.

27. *loc.cit* ref 25.

28. Heywood, J (2000). *Assessment in Higher Education*. Jessica Kingsley, London

29. Heywood, J and H. Montagu Pollock (1977). *Science for Arts Students. A Case Study in Curriculum Development.* Society for Research into Higher Education, London. For an American approach see Epstein, H (1970). *A Strategy for Education*. Oxford University Press.

30. Gage, N. L (1981). *Hard Gains in Soft Sciences. The Case of Pedagogy*. Phi Delta Kappa, Bloomington Ill

31. *loc.cit* ref 12

32. For example Owen, S and J. Heywood (1990). Transition technology in Ireland: an experimental course. *International Journal of Technology and Design Education*, 1, (1), 21 - 32

33. Department of Labor (1992). *Learning a Living. A Blue Print for High Performance*. The SCANS report) Department of Labor, Washington, DC. Also reviewed in ref 24.

34. Equivalent to US Department of Labor in England and Wales with a UK brief for higher education

35. Ross, G. M., Parry., and M. Cohen (1993). Philosophy and Enterprise. The implications of Philosophy of the Higher Education Initiative. Pamphlet 50 pp. Department of Philosophy, University of Leeds, Leeds UK

36. Green, S (1990). Analysis of Personal Transferable Skills requested by employers in graduate recruitment advertisements in June 1989, Personal Skills Unit. The University of Sheffield, Sheffield. Includes commentary on methods of teaching likely to achieve the objectives derived from the survey. See ref 27 Ch 2 for a summary.

37. Heywood, J (1994*). Enterprise Learning in Higher Education and its Assessment*. Research and Development series Report no 20. Employment Department, Sheffield.

38. Mentkowski, M (2000). *Learning that Lasts*. Jossey Bass, San Fransisco. Alverno Colle publishes a handbook for students that is regularly reised called Assessment at Alverno

39. The Perry model was promoted by R. S. Culver and J. T.Hackos at the Colorado School of Mines (*Engineering Education*, (1982), 7, (2), 221 – 226). It has subsequently been the subject of several evaluation studies e.g Pavelich, M. J and W.S. Moore (1996). Measuring the effect of experiential education using the Perry model. *Journal of Engineering Education* 85, 287 – 292). R. Marra and B. Palmer considered the relationship of the Perry levels to the ABET 200 criteria. Among their conclusions was that industry required personnel at level 5.(1999. Encouraging intellectual growth. Senior engineering profiles. Proceedings Frontiers in Education Conference (IEEE/ASEE) 2, 12c1- 1 to 6; see same authors Journal of Engineering Education (2000) 89, (1), 39 - 45). Heywood in a review of research on human development related to engineering education has argued that the King and Kitchener model which may be considered a development of the Perry model is to be preferred. This, he argues, is because of its attention to assessment in the liberal arts *per se* at each level of the model. They also developed a test of reflective judgement that has been independently evaluated. (see Heywood (2005) *loc.cit*. ref 25. King, P. M and K. S. Kitchener (1994). Developing Reflective Judgement. Jossey Bass, San Fransisco

39. Christiano, S. J. E and M. Ramirez (1993). Creativity in the classroom. Special concerns and insights. *Proceedings Frontiers in Education Conference* (IEEE/ASEE), 209 –212.

40. Fogarty, R (1993). *Integrating the Curricula* IRI/Skylight Publishing, Palatino Ill

42. Cowan, J (2006). *On Becoming an Innovative University Teacher. Reflection in Action.* SRHE/Open University Press