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Keynote Address

# Engineering Education in Search of Divergent Vision

## Who am I? Who are you? Where are we going?

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## Dedication

To all the friends I have made at the Frontiers in Education (FIE) conferences during the last twenty-five years who have contributed so much to my thinking about engineering education.


## Acknowledgements

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# Engineering Education in Search of Divergent Vision.

### Who am I? Who are you? Where are we going?

**John Heywood**

This paper is about change and its influences on us as individuals and a profession. It is about the future impact of technology on the workforce and its implications for the structure of higher education in general and engineering education in particular. It is argued that divergent visioning will be required to bring about the changes necessitated. The consequences for the individual and the profession will be profound requiring a much greater understanding of, who we are and what we want to be as our circumstances continually change.

For some unknown reason I kept thinking that the theme of the conference was “globalization” not “internationalization”. While there are similarities between these terms they do have different meanings. For my purpose I take the concepts of globalization and internationalization to mean “interdependence”. While it is evident that technology makes us more and more interdependent it is easy to forget that the use of energy makes us more interdependent, or that, peace is disturbed by interdependence, or until the Ukraine air disaster or the annual French and Spanish strikes that we depend on the interdependence of air traffic controllers.

To make matters worse I kept confusing the term “innovation” with “change”. Perhaps that is because unconsciously I wanted to talk about “change”. In any event “Innovation” is an outcome of “change”.

I wish to focus on two kinds of educational change and four factors that can inhibit or enhance change namely, plausibility, readiness, identity and power [1]. Other dimensions of and strategies for change have been discussed at FIE and in the journals [2].

In education change takes place at the level of the system, or its sub-units: at the same time it impacts on individuals and together with other factors affects the individual internally, that is his or her personal development.

At the level of the system and its contributing organizations Marzano distinguishes between first and second level change [3]. First order changes are relatively easy to bring about, not so second level changes which Marzano and his colleagues described as "dramatic" [4]. Others hold that all such change is "disruptive" [5]. It is certainly "divergent".

Dramatic change seldom happens in education either with the curriculum, its practice or organization. When dramatic innovations occur they are seldom sustained and the system soon returns to its previous equilibrium. I hesitate to infer "normality". The one major innovation in the twentieth century in higher education of which I have some knowledge is the ability-led curriculum of Alverno College in Milwaukee which, when it was created in the early nineteen-seventies, transformed the institution [6]. The Alverno model has influenced many institutions and individuals including myself [7]. During the same period a model of the engineering curriculum as applied science has persisted and such change that has taken place has been mainly in response to changes in technologies and new understandings in the sciences. Some subjects disappear, new ones emerge, some are modified but the same mode of teaching and the

same policy intent remains, although there have been some significant innovations that engineering educators have taken up [8].

In this respect IT techniques continually infiltrate the system but by and large their development and adaptation is rather like that of the automobile where minor changes are made to a particular model year on year out. IT is seen as a mechanism of educational support or substitute, but not for radical changes in the curriculum, teaching, or classroom design. Some politicians hope that the widespread introduction of technology and on-line courses will reduce the costs of higher education although Christensen and his colleagues believe it will be the disruptive force that will change higher education [9]. However, policy makers are in general not prone to causing "dramatic change", and they avoid fundamental questions about the aims of higher education and within that template engineering education. In this respect those who have influence over policy in engineering education are no different.

Engineering education policy makers certainly look ahead but their views, for that is what their propositions are derive from current outlook and current predictions. The US report on *The Engineer of 2020* is a good example [10]. As Kourdi has pointed out the past is seen as a guide to the future [11]. The question is whether the future should be more of a guide to the present. They encourage much discussion and undoubtedly cause some renewal. Nevertheless, challenging though such reports may be, they remain within a convergent focus although they will undoubtedly encourage many minor innovations. What then are the factors that impede or enhance change?

Disruptive change is more likely to be imposed from the outside than it is to develop from within. But outside factors can also inhibit

change. While it is currently the practice to laud globalisation, internationalism can lead to conformity and as such impede change. Richard Morrison the music critic of the London *Times* argues that the intensively competitive world which is the product of globalisation leads to uniformity and conformity [12]. One reason for this is the loss of regional cultures. He writes: "Since time immemorial people have always copied success, but the internet has made it easier than ever before. Just as symphony orchestras and football teams slavishly imitate each other rather than building on inherent regional strengths and characteristics, so do architects, chefs, pop stars, film makers, supermarkets, fashion designers, and virtually every kind of manufacturer".. [...] "one style fits all". Breaking out of this box is exceedingly difficult but Morrison sees hope and cites the growth of little local breweries as an example. We should not forget that micro-breweries have been made possible by changes in technology. However, we should look elsewhere for the factors that are likely to induce radical change.

If Morrison had inserted "engineers" after architects he would have said it all. When we read wanted "creative engineers" we have to remember that creativity is defined by this global cultural box. At the operational level of engineering education this drift to conformity is to be seen in the world-wide adoption of "outcomes" and "competences" to define the engineering curriculum. Mónica Edwards, Edmundo Tovar and Óliver Soto show how in 2008 Spanish engineering education was being influenced by these developments [13]. They are a reminder that as John Walkington an Australian investigator argued change is a journey, not a blue print [14]. It is non-linear and loaded with uncertainty. Perhaps part of that journey will be to greatly reduce the number of competencies into a few core categories as Tovar and Soto have done [15], and maybe there will be a reappraisal of the

meaning of competence. For example, a study of engineers at work in Volvo by the Swedish management theorist Jörgen Sandberg throws a quite different perspective on the traditional understanding of "competence" [16].

For such a re-appraisal to happen the institutions that regulate engineering education will have to be "ready" to respond to or create such a debate and the arguments will have to be plausible [17]. An innovator stands little chance of implementing an idea if it is not "plausible" [18]. But sometimes while an idea may seem to be plausible it is not possible to sustain it because its sponsors lack the knowledge that could bring about its development. In the 1950's the organizers of cooperative courses in the UK lacked the knowledge that would have enabled them to better integrate industrial and academic training [19]. Here-in lies the importance of organisations like ASEE, SEFI and FIE, the dialogues they promote and the networks that arise. In this respect FIE has helped to create plausibility for those who were interested in philosophy and engineering. Now FIE could help extend engineering education's knowledge base to the study of the theory and practice of the curriculum and policy making both of which require a firm philosophical base. Whereas a few years ago it would not have been "plausible" to seek such a development recent discussions suggest that institutions are now "ready" for such a development.

Today from a policy making perspective understanding "integration" and the nature of "competence" is important because of industrial perspectives on what the role of a university education is. In sum, for a something to be plausible prior knowledge is required.

There is one other dimension of change I wish draw to your attention, and that is "identity". It is a term that is very familiar which was

brought to public attention by the German born American psychoanalyst Erik Eriksen [20]. He related it to the search for identity that goes on between the ages of 12 and 18 during which time the adolescent tries to find his or her identity. We might put it in terms of a search to answer the question "Who am I?" Eriksen took the view that if a person does not solve that problem that person is likely to experience role confusion. Given the many pressures on youngsters in this age group a few of them are likely to become very confused. Very few will avoid some confusion, and they will all change to some extent or another: and that will be the sign of an individual's development. This is what I meant by internal change at the beginning. It is brought about by the interactions we have with other people. Today we are concerned with the relationships that a person has with the education community on the one hand and on the other hand the professional community and the confusions that exist between the two.

The difficulty with Eriksen's stage of identity is that it can so easily give the impression, unintended I am sure, that a person reaches maturity at the age of eighteen [21]. My own view is somewhat different. It is my submission that we continually search for an identity throughout life and that we experience many confusions between work and life as well as within work and life [22]. Consequently all change involves a capacity to deal with ourselves as we construct, maintain and develop our identity. We go along with that which leaves our identity unaffected. We drive for change if we believe we will find our identity. All change involves a capacity to deal with ourselves as we construct, maintain and develop our identity. We resist that which we think will shatter our identity. All change involves changes in attitudes, beliefs and values. Our conceptual understanding continually develops. We are continually

seeking the answer to the question “Who am I? In its restricted form, for example in relation to the group we are in, and in its general form in relation to the “life” we live. It is the confusions that are caused by the profession of engineering education that are of considerable importance to us.

All this may be said of groups [23] for groups are but aggregates of individuals that form and retain the like-minded and remove the difficult. It may be that answers to “who am I?” are impeded by the group. A group whose members strongly subscribe to the same norms and values is likely to be cohesive either in the face of or in the pursuit of change. Professional societies can impede change just as they can force change. The question for professional groupings such as ourselves is “who are we?” Answers to this question are extremely difficult for the engineering education community.

A person entering engineering education is faced with the problem that since low status institutions emulate higher status institutions in order to gain similar status, it is almost inevitable that the engineering educator will be required to do research. In some institutions teaching is almost an afterthought. But for many the role confusion brought about by having to have an allegiance to two quite different roles may be considerable. If teachers come via a doctorate straight into engineering education then their primary professional identity is likely to be with research, and their professional identity is shaped by that research and membership of a professional organization. Their education has prepared them to be researchers not teachers.

If engineering education is a profession dignified by a discipline of study that defines its areas of interest then why does the engineering educator not have to have a title that distinguishes her or him as a professional educator like the PE in the United States and the C.Eng in

Britain and Ireland? Something like PEE (Professional Engineering Educator). The immediate answers would seem to be that role confusion prevents them establishing an identity, and related to that a simplistic view of what education is.

However, there are a small but increasing number of countries that now require university teachers to be trained, the UK and Sweden [24] among them, although their requirements differ. I talked about this development in the UK as long ago as 1993 at FIE. The case was being established for general training courses. However at FIE 96 I argued that engineers should undertake their own training and showed how even then there was a sufficient body of knowledge among the engineering education community to offer a course of training similar to that provided for graduates seeking to teach in my university. ERM shot this idea down in 1999 at Puerto Rico but they were sufficiently engaged to sponsor a forum on Instructional Leadership at the next FIE. If this idea is plausible, indicators such as the IGIP accreditation [25] suggest that it is then we should be asking national societies for engineering education to provide certification for those who wish to be recognized for their study and practice of the discipline of engineering education, and who wish to become "extended" rather than "restricted" professionals [26]. That would be a "dramatic" change. It would certainly be subversive if not disruptive. Are we engineering educators "ready" for such a development?

At first sight there would seem to be a contradiction in what I am saying for I have previously argued that professionalism may impede change. But I have also argued that for change to take place there has to be a knowledge base and a forum for discussion that is recognized by those responsible for policy. That is the task of a professional society which should help us answer the "change" question – "Where

are we going?" We need to be able to answer this question because change is being forced on us all the time and we need to answer it from a profoundly philosophical base. In so far as the individual is concerned it is the same question as "who am I?" - Because we also have to understand "where we are at".

The philosophies of positivism and utilitarianism from which prevailing business models are derived have been the driving force in the expansion of higher education and the direction it has taken during the last fifty years, and this where we are at [27]. One consequence of this has been that policy advising reports have not made any philosophical analysis of education. It has been assumed that there is no debate to be had about the aims of education [28]. It is a means-end activity. Science will solve everything and the purpose of education is to prepare people to serve the economy. In this view students are commodities to be manipulated by the system into jobs. Industry wants colleges to prepare students for immediate work in the jobs they currently have. In the British Isles this division of labour by subjects influences the whole culture not just pre-university education. Students come to believe that education is there to train them for jobs and it should get on with doing that job. Their answer to "who am I?" is associated with that culture and not so much with themselves and their general belief systems or their role in society.

Families reinforce these attitudes. While they may pay lip service to "educating the whole person" their concern is with an education that will provide their children with a good job. Naturally many students choose jobs they believe will bring good financial rewards, and or status, and this determines their choice of subject at university. Anything that gets in the way of learning that subject is dismissed which is why it is so difficult to introduce any element of liberal study

in engineering courses. Identity becomes tied up with engineering and nothing else. Aiming for a job avoids the confusion of indecision.

Unfortunately with changing technology and accompanying changes in social structure they are likely to be quickly disillusioned. They will find that in the US that there is no shortage of engineers and technologists, indeed there is some middle aged unemployment. There is no reason to believe that other industrialized nations will not follow the US. They will also find that only one in 4 STEM degree holders is in a STEM job, and they will find the big firms are anxious to keep wages down by employing young workers for a few years only [29]. They are likely to have a number of jobs during their careers. One thing seems certain, in the future, workers will have to be much more adaptable and flexible than they are now, and many work environments will have to change [30], and life-long learning will be an imperative.

For those following in their footsteps the situation will be even worse because while qualifications will be essential to get even low status jobs the cost of maintaining the present structures of higher education may increase to the point where many families may not be able to afford a higher education for their offspring, or their offspring will not be able to afford the loans that will be required to see them through university. Given that this is the case it is surprising that no one is questioning present structures but, given what we know about "change", it is not. As we have seen if change is to be bought about ideas have to seep into the system, and this is beginning to happen.

For example, in the United States tuition fees rose by 274 % between 1990 and 2009, and this was more than the price of any basket of goods or services (31). In the UK John Denham, a former universities minister for England and Wales suggests that the structure of the

university course should be changed from three years to two years, each year being of 39 weeks duration with a consequent reduction in the costs of a university education by 20%, and this would apply for 30% of the entrants. The idea of a two year course is not new in England and was discussed in the early nineteen-sixties by some Cambridge academics. The effect on engineering would be considerable because to obtain professional status four year degree programmes are required. What implications will a two year degree have for our understanding of what it means to be a professional person, in a system where life-long learning is no longer a platitude but a *sine-qua non*? Questions that will need to be answered include- What will be required from continuing professional development? And, what responsibility will employing organizations have for that professional development?

Different nations will respond to these needs in different ways. Those with four year programmes may think that a three year basic programme is all that is necessary. As for professional programmes like engineering which require four and five years to qualify it may be that a more useful approach would be for students to go into industry for a few years on completion of their first degrees and then take a higher level qualification.

Alan Cheville has taken this thinking somewhat further. He suggests that students should take out an insurance policy for a life-long engagement with their university so that they can either return to their university at intervals, or use e-learning to obtain immediately required knowledge, or knowledge for further personal and professional development. He envisages that there will be many pathways along which individuals can travel. The implications for credentialing are profound. First, credentials should no longer signify

the end of education but should simply be indicators of personal and professional progress. Second, this implies that assessment is a record of progress that indicates a *labour arena* covered by the skills a person possesses [32]. But it is also about life and coping with life and the skills necessary for this to be achieved, the most important of which is a philosophical disposition or as some would say a reflective capability. A business model is not appropriate neither is it appropriate for basic higher education. It is evident that it is the application of that model that has led to business complaints that students do not have the specific skills they need [33].

If it is correct that many individuals will have to change jobs on a number of occasions during their lifetime then industrial organizations will have to accept that they share with society, (probably represented by an institution of higher education) responsibility not only for the professional but personal development of the individual. Again, if individuals are likely to work for much less time than they have done in the past as some forecasters predict the personal begins to become more important than the professional. That would be to correct the present imbalance between the professional and the personal for it is the "personal life" that is the driver of all our behaviour.

John Macmurray the Scottish philosopher distinguished the notion of "society" (a cooperative enterprise maintained by justice and a harmony of functions) from "community" (the full expression of their togetherness by members of a society – in personal communion through culture). Summarising Macmurray's views on education given in the Payne lectures to the College of Preceptors Costello writes that "*Education* [...] *must aim to serve both realities at once but with a vision that situates the functional, social goal (learning skills and aptitudes) as a subordinate dimension within the cultural*

*one (personal formation and development in community). These are not two separate kinds of education but two aspects of the same education process* [...] *It is impossible to teach any technical growth whatever without producing some cultural effect. Equally it is impossible to enhance expression without stimulating growth in technical competence. But the latter should be integrated within the former and directed to its service. In other words, every growth in technical know-how should be taught in the context of responsibility - to people and to our culture*"[34], and I would add to ourselves.

In terms of the thesis offered here, it provides for the reconciliation of the personal and professional identities.

Macmurray would have agreed with Albert North Whitehead that "*there is only one subject matter for education, and that is life in all its manifestations"* [35]. If we are concerned with learning about life in all its manifestations then we are likely to be more adaptable and flexible and to quote John Henry Newman "*to fill any post with credit, and to master any subject with facility*" [36].

There can be no contradiction between a liberal education properly constructed so that a person experiences an enlargement of mind and the demands of industry. Those demands when analysed are of two kinds. The first is for specific kinds of knowledge some of which could quite evidently be provided by industry. The second is for interpersonal skill which necessarily embraces the "affective", a point which is illustrated by "person centred approach adopted by the Viennese researchers Renate Motschnig-Pitrik and Katherine Figl for the development of these skills among computer scientists [37].

As I have argued in other papers Newman's statement of the outcomes of a liberal university education is entirely consistent with the aims of

education proposed by MIT in *Made in America. Regaining the Productive Edge*, or the UK Employment Department's statement of learning outcomes in *Assessing Enterprise Learning,* or more significantly Sternberg's list of abilities that contribute to intelligence in *A Triarchic View of Intelligence* [38]. Newman's "idea" begins with view that a "person" is something very much more than a cognitive processing machine. Newman's philosophy is enriched by Macmurray's understanding of how we become a person.

Persons only develop as persons in relation to other persons. We come to be who we are as personal individuals only in personal relationship. It is that view which is the justification for the collegiate organization of a university. It is that view which gives credence to cooperative learning. What it does not give authority to is learning for personal skill development in groups comprised of students from a single subject. Engineers in the conduct of their work have to deal with all sorts of individuals. The Australian engineer James Trevelyan argues that the principle task of the engineers is liaison. The accomplishment of this task requires engineers to speak many languages. In other papers I have tried to demonstrate that the task of engineering requires an integrated approach to its study and at the same time I have tried to show how engineering and technological literacy can provide a base for a trans-disciplinary approach to liberal education relevant to today's society. The two-year base model that I have described elsewhere would be of that kind, and for me it shapes the answer to the question "where should we go?"

A weakness of engineering education is that it has not bothered with either the curriculum as a serious proposition for study or with policy making. That in my view is where it should now direct its attention. FIE could make a significant contribution by inviting papers in these

two areas where the evidence I have presented strongly suggests the need for divergent visioning.

**Notes and references**

**[1].** Heywood, J (2006). Factors in the adoption of change: identity, plausibility and promoting educational change. *Proceedings Frontiers in Engineering Conference.* T1B- 9 to 14.

[2]. (a) Froyd, J. E., Penberthy, D., and K. Watson. (2000). Good educational experiments are not necessarily good change processes. *Proceedings Frontiers in Education Conference*, 2, F1G-1 to 6.

(b). Borrego, M and C. Henderson. (2014). Increasing the use of evidence-based teaching in STEM higher education. A comparison of eight change strategies. *Journal of Engineering Education*, 101, (2), 220 -252.

(c). Henderson, C., Beach, A., and N. Finkelstein. (2011). Facilitating change in undergraduate STEM instructional practices: an analytic review of the literature. *Journal of Research in Science Teaching*. 48, (8), 952 – 984.

[3]. Marzano, R. J., Waters, T and B. A. McNulty. (2005). *School Leadership that Works. From Research to Results.* Alexandria, Va. Association for Supervision and Curriculum Development. They argue that one of the reasons second level change is difficult to implement and sustain is because change agents use practices that are suitable for first order but not second order change

[4]. Dewey's democratic schools are often cited as one of the major initiatives that failed.

[5]. Christensen, C. M, Horn, M. B., Caldera, L., and L. Soares. (2011). *Disrupting College. How Disruptive Innovation Can Deliver Quality and Affordability to Post-Secondary Education*. Center for American Progress. Innosight Institute, Harvard University.

[6]. (a) Alverno College Faculty. (1994). *Student Assessment-as Learning at Alverno College*. Milwaukee, WI. Alverno Institute.

(b) The Alverno programme is well documented and researched. See Mentkowski, M and Associates (2000). *Learning that Lasts. Integrating Learning, Development, and Performance in College and Beyond*. San Fransisco, Jossey Bass.

The development of the Alverno curriculum began in 1973 (circa) and was the brainchild of a Religious Order of Sisters who wanted to rejuvenate a small liberal arts college for women in Milwaukee. Their programme which has been thoroughly evaluated (Mentkowski, 2000) has brought them world-wide renown. Within the United States the college has directed faculty teams in 23 institutions in the design, "field testing of performance assessment instruments that

directly assessed students progress in developing the abilities inherent in their institution's stated outcomes" (c). Its approach has been of interest to engineering educators in the United States

Alverno College defines assessment as "a multidimensional process of observing and judging an individual in action on the basis of public, developmental criteria" (p 6, (a)). This process was brought to bear on the assessment of eight domains of competence each of which was described in four levels of achievement in general education and two advanced levels specific to the student's selected major and minor subjects (a). It is important to emphasise that these are levels of conceptual development and not a check list of items that contribute to the level 6 item (exhibit 1). Each level represents a greater degree of comprehensiveness. By 1999 the term 'competence' had been replaced by 'ability' although the domains remained the same (see exhibit 2). Although this is not the reason given by Mentkowski it is this writers impression that one of the judgments of competency based teacher education programmes is that they de-professionalized teaching because they were too reductionist. This is the last thing that the Alverno curriculum is. The scholarly interpretation must be that Alverno learned more about what they were doing in terms of development in psychological thinking. Thus in 1983 Anastasi, a distinguished psychometrician had generated the idea of 'developed abilities', and in 1992 Alexander had discussed the concept of domain knowledge so "what can be learned encompasses developed attitudes and domain knowledge". Alverno preferred the term 'developed abilities' to aptitudes "because we have found the language of abilities communicates broadly across educators, employers and professionals [...] moreover, developing abilities is a broader term than acquisition of skill, competence , or expertise. Other terms than ability, such as skill can serve if there is no dichotomy between knowledge and skill, and skills are defined and discussed in the context of learning in the disciplines" (p 10. (b)).

| **An example of the six levels of an Alverno generic ability domain: The development of analytic capabilities** |
|---|
| 1. Show observational skills.<br>2. Draw reasonable inferences from observations.<br>3. Perceive and make relationships.<br>4. Analyze structure and organization.<br>5. Establish ability to employ networks from area of concentration or support area discipline in order to analyze.<br>6. Master the ability to employ independently the frameworks from area of concentration or support area discipline in order to analyze<br>. |

**Exhibit 1. The internal construction of the abilities are regularly reviewed. This is taken from a list supplied for reproduction in Heywood( 2000, p52) by Dr Georgine Loacker (d).**

| **The Alverno College Ability Led Curriculum- Ability Domains to be developed** |
| --- |
| 1.Develop Communication ability (effectively send and respond to varied audiences and purposes<br>2.Develop analytical capabilities.<br>3.Develop workable problem-solving skill.<br>4.Develop facility in making value judgements and independent decisions.<br>5.Develop facility for social interaction.<br>6.Develop responsibility for the environment.<br>7.Develop awareness and understanding of the world in which the individual lives.<br>8.Develop aesthetic responsiveness in the arts. |

**Exhibit 2. The Alverno Abilities (the term domain is this writer's).**

Alverno believed that learning had to be integrative and experiential and that if this was the case assessment had to judge performance. "If learning is to be characterized by *self-awareness*, assessment must include *self-assessment* as well as *expected outcomes* and *developmental criteria* that are public. If learning is to be *active/interactive*, assessment must include *feedback* and elements of *externality* as well as *performance.* If learning is to be developmental assessment must be *cumulative* and *expansive*. Finally if learning is to be *transferable*, assessment must be multiple in mode and context" (c). These principles sit well alongside those of comprehensiveness, coherence and continuity stated in the report on *Knowing How they Know* (see above-section on balanced assessment).

By integration is meant the ability "to continually create new wholes out of multiple parts". It would differ from synthesis in the Bloom *Taxonomy* in so far as synthesis is confined to a single subject. Integration brings knowledge from a variety of different perspectives, and it may be argued that it is the basic skill that is required to have to cope with the ever increasing knowledge that individuals face. It is this skill that the engineer needs to solve the multiple faceted problems he/she and, or teams have to face. It is particularly required by engineering designers and in this respect Deere's view of synthesis shown in exhibit 3 is of more than passing interest. However, both Alverno and Deere would in today's world be criticized for not encouraging the ability to think in terms of 'systems'

(c). Schulte, J and G. Loacker (1994). *Assessing general Education Outcomes for the Individual Student: Performance Assessment as Learning. Pert 1. Designing and Implementing Performance and Assessment Instruments*. Milwaukee, WI, Alverno College Institute.

(d). Heywood, J. (2000). *Assessment in Higher Education. Student Learning, Teaching, Programmes and Institutions*. London, Jessica Kingsley.

(e). Heywood, J (1969). *An Evaluation of Certain Post War Developments in Higher Technological Education*. Thesis, 2 Volumes. Lancaster, University of Lancaster Library.

**Synthesis**.
Whether one is 'designer' or not, as an engineer one is involved in a main stream which synthesizes, therefore is for **sympathy** towards design. The engineer must be aware of the broad features of design, even if his personal creativity is minimal. The features are;

(a) Specification of the **need** in detail.
(b) **Feasibility** demanding the creation of several solutions, and the selection of one (or two) for further study. A corollary is that the quality of analysis must match the quality of the required answer. The student must be able to spot cases where a quick sum will suffice for the moment and those where greater detail is required.
(c) The value of **rigorous** methods in the overall design function.
(d) **Optimization**.
(e) **Implementation** of the chosen solution. The sub-features here are that this often involves large scale management-leading to knowledge of management techniques--and the reconciliation of material supply and production resources with the chosen solution in detail.
(f) At all points in the process of synthesis, the engineer, of whatever 'kind', must be prepared to specify **criteria** by which decisions – often several inter-dependent decisions, can be measured.
(g) The decisions noted above (f) to a large extent also depend on **judgment** and **opinion**. (Surely, any university must set out to cultivate judgment, quite overtly, whatever else it does?)

**Exhibit 3. M. Deere (1968) Communication to a working party on professional examinations of the Society for Research into Higher Education (cited in (e), Vol 1. p 333).**

[7]. Alan Cheville has drawn my attention to Cohen, A. R, Glavin, W.f., Moore, T. E., Allen, S. A and J. P. Zolner (2003) Transformational change at Babson College. Notes from the firing line. *Academy of Management Learning and Education*. 2 (21), 155-180. And, Tosteson, D. C., Adelstein, S. J and S. T. Carver (1994). *New Pathways to Medical Education. Learning to learn at Harvard Medical School*. Cambridge, MA. Harvard University Press.

[8] There is a small but continuing flow of papers and articles that describe efforts to develop problem based learning which in engineering was pioneered by Donald Woods. Similarly with cooperative learning pioneered by Karl Smith.

[9]. *loc cit* ref 3.

[10]. The National Academy of Engineering. *The Engineer of 2020*. Washington, DC. The National Academies Press.

For an example of policy making research see Sheppard, S. D., Macatangay, K., Colby, A., and W. M. Sullivan (2009). *Educating Engineers. Designing for the Future of the Field.* San Fransisco, Jossey Bass.

[11]. Kourdi, J (2010) The future is not what it used to be. *The Professional Manager*. 19, (2), 27 -28. (Chartered Management Institute)

[12]. Morrison, R (2014). Being original is a sin. Send in the clones. *The Times*, August 2nd 2014. P 18.

[13]. Edwards, M., Tovar, E., and O. Soto (2008). Embedding core competence curriculum in compueter in engineering. *Proceedings Frontiers in Education Conference,* S2E- 15 to 20.

[14]. Walkington, J (2002). Curriculum change in engineering education. *European Journal of Engineering Education*. 17, 92), 133 – 148.

[15]. Tovar, E and O. Soto (2010). The use of competences assessment to predict the performance of first year students. *Proceedings Frontiers in Education Conference,* F3J-I to 4.

[16]. Sandberg, J. (2000). Understanding human competence at work. An interpretive approach. *Academy of Management Journal*, 43, (3), 9 – 25. And in respect of lawyers- Sandberg, J and A. H. Pinnington. (2009). Professional competence as ways of Being : an existential perspective. *Journal of Management Studies,* 46, 1138 – 1170.

[17]. *loc.cit*. ref 1.

[18]. Heywood, J (2014). Higher Technological Education and British Policy Making: A lost opportunity for curriculum change in engineering education? *Proceedings Annual Conference American Society for Engineering Education*. Paper 8689.

[19]. In the 1950's idea in the UK of the "integration" of theory taught in colleges with the practiced undertaken in industry in degree level cooperative courses was promoted but it received little serious attention from the engineering educators responsible for the courses (a). It was thought that so long as students recorded a "good" experience that integration had taken place (b). No one undertook an in-depth study to understand whether there was more to integration than this; in consequence no theory of integration emerged. It is only within the last few years that research workers like Peter Blandin (c) in France and Jörgen Sandberg (d) in France have provided the data that could lead to a more profound theory of integration.

(a). *loc. cit* 2(e). Vol. 1.

(b). See for example Jahoda, M (1963). *The Education of Technologists*. London, Tavistock.

(c). Blandin, B (2011). The competence of an engineer and how it is built through an apprenticeship program: a tentative model. *International Journal of Engineering Education*, 28, (1), 57 – 71.

(d). *loc.cit*. ref. 11.

[20]. Eriksen, E. (1950). *Childhood and Society*. New York, Norton. Parents should allow children to explore and not try to get them to conform to their views. This exploration seeks answers to the questions who am I? And, How do I fit in? See also, The problem of ego identity (1956) *Journal of the American Psychoanalytic Association*, 4, 56 – 121. ]. "identity means the partly conscious, largely unconscious sense of who one is, both as a person and a contributor to society" cited by Hoare, C. (2006). Work as the catalyst of adult development and learning in C. Hoare (ed) *Handbook of Adult Development and Learning*. Oxford, Oxford University Press. p 348. On the same page Hoare writes [...] "the original identity construct, as it was defined and described by Erik Erikson from within his and US societal lens, incorporates a decided vocational commitment."

[21]. I have heard distinguished university educators argue that because children and adolescents have studied a wide range of subjects in school that they have received a liberal education. This justifies the four or three years study in one or two subjects that follows school in Irish universities.

[22]. Support for this view will be found in Hoare *ibid*. She writes "both personal dimensions-identity and adult personality-evolve more or less so, as one learns and grows. Each dimension is partly conscious and partly unconscious. When adults are deeply work engaged, they function in a time-out-of-mind zone, rarely surfacing to ponder (if in fact they consciously can) their sense of self and its vital constituents. Clearly other personal attributes are also important to occupational conditions" (p347). Some workers either cannot or will not develop and continue to learn.

[23]. Korte, R. (2007). A review of social identity theory with implications for training and development. *Journal of European Industrial Training*. 31, (3), 166 – 180. "Social identity is one lens through which individuals view their jobs, responsibilities, organizations and even the dynamics of work (eg. Causal attributions). Therefore, social identity becomes an important lens through which people perceive new information, attribute causes, make meaning, and choose to undertake new learning. Without addressing the identity factors stemming from group membership, the success of typical training efforts may fail to realize their promise of improving individual and organizational performance."

[24] Arnold Pears wrote to me as follows " A requirement for educational training for tenure in the academic profession is emrging in many places, it is legislated in Sweden in the Higher Education Ordinance, and a standard formulation is included in all advertisements of academic positions the [...] English version of that text follows:"

"Uppsala University employment regulations require demonstration of good educational ability for appointment to a position as Lecturer. The applicant should have taken relevant courses in the theory and practice of higher education to prepare themselves for the position of 5 full time weeks, or demonstrate that they have acquired equivalent competence by other means. The required courses can be completed during the first two years of employment if necessary".

[25]. IGIP. International Society for Engineering education and Modern Engineering Pedagogy. Accredits courses in engineering education in some European countries.

[26]. The concepts of restricted and extended professionality are due to Eric Hoyle (Hoyle, E (1980). Professionalization and deprofessionalization in E. Hoyle and J. Megarry (Eds). *Professional Development of Teachers: World Year Book of Education, 1980.* London, Kogan Page). They are compared in the table below. See also Warren Piper, D. J. (1994). *Are Professors Professional. The Organization of University Examinations. London*, Jessica Kingsley.

| **Restricted professionality** | **Extended professionality** |
|---|---|
| Skills derived from experience | Skills derived from mediation between experience and theory |
| Perspective limited to immediate time and place | Perspective embracing broader social context of education |
| Class (lecture) room events perceived in isolation. | Classroom events perceived in relation to institution policies and goals |
| Introspective with regard to methods | Methods compared with those of colleagues and with reports of practice. |
| Value placed on autonomy. | Value placed on professional collaboration. |
| Limited involvement in non-teaching professional activities | High involvement in non-teaching professional activities. |
| Infrequent reading of professional literature. | Regular reading of professional literature. |
| Involvement in CPD limited and confined to practical courses. | Involvement in CPD work considerable including courses of a theoretical nature. |
| Teaching seen as an intuitive activity. | Teaching seen as a rational activity. |

**Exhibit 4. Extended versus restricted professionality after Eric Hoyle (1980). (cited by Heywood, J., in *Managing and Leading Schools as Learning Organizations: Adaptability and Change.* Dublin. Original Writing for National Association of Principals and Deputies. P 297).**

[27]. *loc.cit*. ref 5, p 33 ff. Christensen et al demonstrate that universities are conflations of three business models that lead to a complex and confused institution. The models are "solution shops", "value-adding process businesses", and "facilitated user networks. Faculty research is a solution shop type activity. Like manufacturing teaching in universities is a value-added process. Because of the internet networks among students and staff are being developed. Telecommunication companies are examples of facilitated user networks. "Universities have

three fundamentally different and incompatible business models all housed within the same organization" (p 35).

[28]. Nel Noddings considers that talk of aims is a missing dimension in educational conversation (a). Citing Whitehead to the effect "*that there is only one subject-matter for education and that is "Life in all its manifestations"* Noddings points out that "*such statements demand full and lengthy discussion, but that give us a starting point to which we continually return*" (b). Statements about aims naturally reflect the belief and value systems of those that make them so it is not to be expected that there will be a set of aims that will satisfy all outcomes even within the education of engineers (c). But this does not deny the importance of trying to formulate aims because to cite Noddings again "*we need to talk about aims because aims provide the criteria by which we judge our choices of goals, objectives, and subject content*" If we change the direction of the discussion such that developing aims is "*directed (more generally) at the larger society and its policies*" then "*as we ask deeper questions about our aims- why are we doing X-we uncover new problems and new possibilities for the solution of our original problems*" (d). Taken from Heywood, J (2012) Philosophy and undergraduate teaching and learning: thoughts and perspectives for engineering education. *Proceedings Annual Conference of the American Society for Engineering Education*. Paper AC 2012-5378.

(a) Noddings, N (2009). The aims of education in D. J. Flinders and S. J. Thornton. *The Curriculum Studies Reader*. 3rd edition New York, Routledge. P 425

(b) *ibid* p 431.

(c) Schubert, W. H. (1997). *Curriculum. Perspective, Paradigm and Possibility*. Upper Saddle River, NJ. Prentice Hall. Discusses the aims of three different schools of thinking about education.

(d) *loc.cit* ref (a0 pp 414 and 415.

The Christensen report is an example of thinking without aims – or aims understood to be means-end.

[29] Hira, R et al (2014) Bill Gates' tech worker fantasy: column. Silicon Valley has Created an Imaginary Staffing Shortage. *USA Today*, July 27th. http://www.usatoday.com/sotry/opinion/2014/07/27bill-gates-tech-worker-wages-reforms-employment-column/13243305/

[30] Below is an extract from Heywood, J. (2012). The response of higher and technological education to changing patterns of employment. *Proceedings Annual Conference of the American Society for Engineering Education*. Section on "Changing patterns in employment prospects"

If it is possible to extrapolate from the experience of Silicon Valley then the demand for technological manpower is declining irrespective of specific shortages. The US Bureau of Labor Statistics recorded for the decade ending 2010 that techno-scientific employment fell by 19%, and that average wages in Silicon Valley fell by 14% (a).

Related to employment in the software industry is the "E Mail" column of the November 2011 issue of ASEE Prism. It contains an exchange of letters between Professor Allen Plotkin and columnist Vivak Wadwaha about an article that Wadwha had written in the September issue of the magazine (b). He had asked, why should a company pay a 40 year old engineer a considerable salary if it can get the same job done much more cheaply by an entry level employee?. He said that it was happening in the software industry. "After all the graduate is likely to have more up-to-date skills and work harder". An Irish Academic told this writer that firms told him that they wanted young graduates who could do the job immediately and that they would keep them from seven to nine years! Relate that to Wadwha who said that "if you listen to the heart-wrenching stories of older engineers" (who have become unemployed) "you learn they have a great many skills, but no one wants to hire them". Professor Plotkin questions whether or not anyone would want to work in an industry that treats its workers in the way described in this article. Nevertheless it seems there is a serious unemployment problem among middle aged and older engineers in some sectors of the US. Wadwha's response is to cite the metaphor of a roller coaster and suggest that the universities need to prepare students for that ride so that when the need arises they are able and interested to change jobs. Hence the need to take the concept of life-long learning more seriously and to design courses of continuing professional development that support engineers on that rollercoaster. Such programmes are likely to be as much about personal development as they are about specific topics in engineering.

In the same vein G. Paschal Zachary writing in IEEE Spectrum said that often emerging technologies require far fewer workers (c), The new titans of Silicon Valley employ far fewer workers than the older titans and this is likely to apply equally to their offshore establishments. At the same time some emerging technologies destroy jobs. He also draws attention to the phenomenon of "jobless" innovation. This occurs when an innovation is off-shored to countries where qualified manpower is much cheaper to employ. Zachary goes on to as "How can Americans capture more of the employment associated with job expanding innovations. They can start by examining their faith in the traditional equation of technological innovation with healthy markets".

There is at least one American who has done this, Jim Clifton the CEO of Gallup. In this book The Coming Jobs war based on Gallup studies in numerous countries he comes to ten conclusions (d). One of them reads "entrepreneurship is more important than innovation. The supply and demand is backward here. Almost all countries, states and cities have bet everything on innovation. Innovation is critical, but it plays a supporting role to entrepreneurship. The investments should follow rare entrepreneurs versus the world-wide oversupply of innovation. Put another way, it's far better to invest in entrepreneurial people than a great ides" (p 187).

Elsewhere he argues that economies ride on the backs of small to medium-sized business. Most jobs occur when entrepreneurs start companies. The reader of that book will have to look long and hard for references to higher education, engineers and technologists.

Finally, another twist to the problem of technical employment and innovation will be found in the November 2011 issue of *ASEE Prism*. Mark Matthews, its editor, wrote "more than jobs is at risk if the United States continues to bleed manufacturing operations [...] loss of manufacturing could also diminish the American capacity for innovation. However, from the pessimism comes hope, even if there is a sting in the tail. He writes, "Advanced manufacturing, if it succeeds, offers a bright future for engineers [...] Laid-off industrial workers will not fare so well, since part of what makes the new techniques attractive is greater productivity. What will be needed are skilled technicians with a grounding in math and science" which seems to be somewhat contradictory since that does not presage need for engineers. Support this view will be found in Washington State's Assessment of Education Credentials and Employer Needs. Eleven Centers of Excellence have been established by the State in two year colleges. The occupations for which skills standards have been developed are all for varying grades of technician and craftsman (e). And, in respect of manufacturing the State of Minnesota has established a career and education pathways for a manufacturing and applied manufacturing worker that can bring them as far as middle management on the one hand and on the other hand an M.S degree (f). According to the President of the Illinois Community College Trustees Association Barbara Oilschlager 41% of jobs will be at the middle level requiring more education than high school but less than a bachelor's degree . In the UK this would be called technician level education and distinctions are made between two levels of technician those requiring one or two years beyond high school and those requiring a basic degree e.g. engineering technology.

The overall picture among the industrialised nations seems to be either one of decline in the higher technological workforce, and/or one in which demand is being met.

(a) Cited by Zachary, G. P (2011). Jobless Innovation? *IEEE Spectrum*, April, p 8.

(b) Wadhwa, V (2011). Leading edge: over the hill at 40. *ASEE Prism*, p 32.

(c) Zachary, G. P (2011). Jobless Innovation? *IEEE Spectrum*, April, p 8.

(d) Clifton. J (2011). *The Coming Jobs War*. Gallup Press, New York.

(e) Cited by Sparks, E and M. J. Waits (2011). *Degrees for what Jobs? Raising Expectations for Universities and Colleges in a Global Economy*. National Governors Association, p 20, 23.

(f) *ibid* pp 22, 23, 26, 27. *Minnesota Measures: 2009*. Report on Higher Education. Minnesota Office of Higher Education.

There has been a continuing flow of publications (and debate) since this was written that support this contention, but there are opposing views and some say with some force that the data is confusing. An interesting paper published by the Metropolitan Policy program of the Brookings Institute tries draw conclusions from a big data analysis of job vacancies in relation to STEM skills. It shows that the median duration for advertising for a STEM vacancy is more than twice as long as for a non-STEM vacancy. Computer skills are associated with the highest salaries and the longest advertisement duration. But it does not report any micro (qualitative) studies of employers and the impact of not acquiring such personnel has on the overall objectives of the business. The value of the report lies in the light it throws on the range of occupations where some STEM skills are required to a greater or lesser degree. (Rothwell, J. *Still Searching. Job Vacancies and STEM Skills*. Brookings, July 2014). It is of interest to compare it with the 1990 Sheffield study of adverts for graduates (Summarised in Heywood, J (2005) *Engineering Education: Research and Development in Curriculum and Instruction*. Hoboken, NJ. IEEE/Wiley).

[27] This phrase has a dual connotation. It refers both to the large work unit as well as to units within large units.

[31] *loc.cit*. ref 5, p 8.

[32] Youngman, M. B., Oxtoby, R., Monk, J. D and J. Heywood (1978). *Analysing Jobs*. Aldershot. Gower Press.

"Our concept of a' labour arena,' that is, of a group of skills which is already possessed or which may be readily acquired, crosses the divide of job perceptions derived from job titles" p 106.

[33] Rothwell, J. (2014). *Still Searching. Job vacancies and STEM skills*. Brookings Institute. Shows that employers seek quite specific skills whereas universities wil be concerned with the development of generic skills.

[34] Costello, J. E. (2002). *John Macmurray. A Biography*. Edinburgh, Floris books. pp 316 ff.

[35] Whitehead, A. N. (1932). *The Aims of Education*. 2nd edition. London, Ernest Benn (chapter 1).

[36] Newman, J. H.(1873) *The Idea of a University. Defined and Illustrated*. 1947 edition edited with an introduction by C. H. Harrold. New York, Longmans Green.

[37] Motschnig-Pitrik, R and K. Figl (2007). Developing team competence as part of a person centered learning course on communication and soft skills in project management. *Proceedings Frontiers in Education Conference*, F2G- 15 to 21.

[38] The statements referred to in the text are:

"University training is a great ordinary means to a great ordinary end: it aims at raising the intellectual tone of society, at cultivating the public mind at purifying national taste, at supplying true principles to popular enthusiasm and fixed aims to popular aspiration at giving enlargement and sobriety to the ideas of the age, at facilitating the exercise of popular power, and refining the intercourse of private life. It is the education which gives [persons] a clear conscious view of [their] own opinions and judgements, a truth in developing them, an eloquence in expressing them; and a force in urging them. It teaches [them] to see things as they are, to go right to the point, to disentangle a skein of thought, to detect what is sophistical; and to discard what is irrelevant. It prepares [them] to fill any post with credit, and to master any subject with facility. It shows [them] how to accommodate himself to others, how to throw himself into their frame of mind, how to bring before them his own, how to influence them, how to come to an understanding with them, how to bear with them. [They] are at home in any society, [they] know when to speak and when to be silent, [they are] able to converse, [they are] able to listen, [they] can ask a question pertinently, and gain a lesson seasonably, when [they] have nothing important [themselves], [they are] ever ready, yet never in the way, [they are] a pleasant companion, and a comrade you can depend upon; [they know] when to be serious and when to trifle, and they have sure tract which enables [them] to trifle with gracefulness and to be serious with effect. [They] have the repose of mind which lives in itself, and which has resources for its happiness at home when it cannot go abroad. [They have] a gift which serves them in public and supports [them] in retirement, without which failure and disappointment have a charm. The art which tends to make a [person] all this, is the object which it pursues as useful as the art of wealth or the art of health, though it is less susceptible of method, and less tangible, less certain and complete in the result."

**Exhibit 5. The purpose of a University training as enunciated by J. H. Newman in the seventh discourse in *The Idea of a University* (see ref 35).**

MIT should broaden its educational approach in the sciences, in technology and in the humanities and should educate students to be more sensitive to productivity, to practical problems, to teamwork, and to the cultures institutions and business practices of other countries.

Creaet a new cadre of students and faculty characterized by (1) interest in, and knowledge of, real problems and their societal, economic and political context: (2) an ability to function effectively as members of a team creating new products, processes and systems; (3) and ability to operate effectively beyond the confines of a single discipline: and (4) an integration of a deep understanding of science and technology with practical knowledge, a hands-on orientation and experimental skills and insight.

Where possible, revise subjects to include team projects, practical problems, and exposures to international cultures. Encourage student-teaching to instil a stronger appreciation of life-long learning and the teaching of others. reinstitute a foreign-language requirement in the undergraduate admissions process.

**Exhibit 6. The argument in this paper is that kind of person who will achieve these goals is the kind of person that should result from a liberal education. The extract is from *Made in America: Regaining the Productive Edge* by Dertouzos, M., Lester, R. K and R. M. Solow. Cambridge, MA, MIT Pre**

**Cognitive knowledge and skills**

1. **Knowledge**:- Key concepts of enterprise learning (accounting, economics, organizational behaviour, inter and intra personal behaviour).
2. **Skills**:- The ability to handle information, evaluate evidence, think critically, think systematically (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 leader.

**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 know one's self and one's values, and to able to assess one's actions.

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

**Exhibit 7. 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 UK Employment Department -1991 ( Cited in Heywood (2005)** ***Engineering Education: Research and Development in Curriculum and Instruction.*** **Hoboken, NJ. IEEE/Wiley.**

1. **Practical problem solving ability**: reasons logically and well, identifies connections among ideas, sees all aspects of a problem, keeps an open mind, responds to other's ideas, sizes up situations well, gets to the heart of the problem, interprets information accurately, makes good decisions, goes to original sources of basic information, poses problems in an optimal way, is a good source of ideas, perceives implied assumptions and conclusions, listens to all sides of an argument, and deals with problems resourcefully.
2. **Verbal ability**: speaks clearly and articulately, is verbally fluent, converses well, is knowledgeable about a particular field, studies hard, reads with high comprehension, reads widely, deals effectively with people, writes without difficulty, sets times aside for reading, displays a good vocabulary, accepts norms, and tries new things.
3. **Social competence**: accepts others for what they are, admits mistakes, displays interest in the world at large, is on time for appointments, has social conscience, thinks before speaking and doing, displays curiosity, does not make snap judgements, assesses well the relevance of information to a problem at hand, is sensitive to other people's needs and desires, is frank and honest with self and others, and displays interest in the immediate environment.

**Exhibit 8. Abilities which contribute to intelligence. Obtained from questions about the nature of intelligence, academic intelligence, and unintelligence put to experts in research on intelligence and lay persons by R. H. Sternberg and his colleagues. Among the findings was the fact that research workers considered motivation to be an important function of motivation whereas lay persons stressed interpersonal competence in a social context. In R. H. Sternberg (1985) *Beyond IQ. A Triarchic View of Intelligence*. Cambridge University Press.**

Dr John Heywood is currently interested in the development of a philosophy of engineering education as distinct from the philosophy of science education. He became interested in philosophy while working at the Marconi Company in the nineteen fifties. When he moved to teaching radio at a London Technical College he was also given responsibility for the liberal studies programme for engineering students. While at this college he undertook published research into his own teaching, and has since widely promoted the idea of teaching as research. He has published extensively on this topic. During this period he also directed the work of the radio-electronics section of the British Astronomical Association (BAA) and led the BAA and Radio Society of Great Britain's teams that observed Sputniks I and II. For his work in this area he received two gold medals and a silver medal from the Junior Institution of Engineers.

In the early nineteen sixties he undertook a policy making evaluation of developments in higher technological education in newly created Colleges of Advanced Technology. After that he was the first person in the UK to be appointed to a tenured lectureship in higher education at the University of Lancaster, During this period he pioneered the introduction of engineering studies in high schools, and devoted considerable time to studies of the engineering curriculum and its assessment. He has continued this work until the present day. In the 1970's he directed research for an Irish Government Committee on School Examinations, and subsequently became director of teacher education in the University of Dublin. In the 1990's he advised the UK department of Employment on the assessment of enterprise learning. Since he retired in 1996 he has devoted himself to problems of engineering education and regularly contributes at the yearly ASEE and FIE conferences, He was awarded the best research publication award of the Division for the Professions of the American Educational Research Association for his book on Engineering Education: Research and Development in Curriculum and lnstruction in 2006, and was elected a Fellow of ASEE in 2007. He has some 140 publications including 12 books. He was the foundation editor of the *International Journal for Technology and Design Education*. He is a Fellow of the College of Preceptors, a fellow of the Chartered Management lnstitute, and a Fellow of the Royal Astronomical Society.




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