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The Response of Higher and Technological Education to Changing Patterns of Employment

Abstract

Educational policy making is seldom discussed at meetings of engineering educators except in so far as they relate to implementation, as for example the response to ABET 2000 or the Bologna Agreement. It is widely believed among engineering educators that there is a continuing shortage of highly qualified engineers and scientists. Public acceptance of this view ensures continued high levels of funding. Coupled to this axiom is the supply side view that an insufficient number of quality candidates are emerging from the schools as candidates for STEM courses. Such views are not confined to the United States but will be found in other industrialised nations. Relatively little attention is paid to the demand side of the equation. However, the data that is available challenges these axioms and suggests that while there may be specific shortages there is no general shortage. It is noted that there are numbers of middle-aged engineers who are unemployed. It is also noted that technological innovation does not guarantee an increase in employment as in the past, and that in the extreme case technology may create a new technology without reference to the work force.

Most complaints from employers about the products of higher education do not focus on their technical knowledge but on their failure to develop what in the UK have been called "personal transferable skills".

The implications of findings for educational policy makers are (1) that policy making should be undertaken from a systems perspective that embraces elementary education at one end of the spectrum and lifelong (permanent) education at the other: (2) that engineering educators together with industrialists should pay much more attention to lifelong education, and therefore in continuing professional development for engineers in both technical and personal dimensions: (3) that engineering educators should better prepare students with the skills of flexibility and adaptability required to cope with ever changing knowledge, that is "personal transferable skills".

These axioms are reinforced by a recent report from the National Governors Association in the US that from an evaluation of changing patterns of employment and skill demands, recommends that the states should pay much more attention to the needs of employers. In so doing the authors challenge the states to reduce the traditional emphasis on four-year liberal arts programmes and focus more on job (vocationally) oriented courses. There is a responsibility on those engaged in engineering literacy to consider how it might act as a bridge between these apparently opposing philosophies.

Introduction: problems with changing the curriculum

Educational policy making is seldom discussed at meetings of engineering educators except in so far as they relate to implementation, as for example the responses to ABET 2000 in the United States or the Bologna agreement in Europe. Worse evaluation of such policies is often haphazard and changes in the curriculum are often predicated by technological change rather than policy. Computer science and technology courses and programmes in bio-engineering are examples of large developments readily accepted by the educational community because they are perceived to be technologically necessary. Others that involve the development of knowledge dimensions from the humanities and social sciences are not received with welcoming arms even when their necessity can be demonstrated by the needs of technology. The consequence is that, as in all other knowledge areas curriculum change is the result of a continuous flow of small changes [1]. The process is very similar to that which (happens in the year to year changes made to a particular automobile).

Every now and again some innovation necessitates radical change and re-thinking of how things need to be done in the future. In the writers lifetime the big change for him was the advent of the semi-conductor especially the transistor in electronics. Thermionic vacuum tubes became redundant overnight, and in the author's own field of study the problem of noise in amplifiers was radically changed for the better. Teachers had to re-learn quickly to adapt to the new techniques. From the broader perspective it created a whole new industry and a demand for many highly qualified persons in these new fields. Its effects were felt worldwide [2]. The same thing happened with the information technology industry.

However it seems that such dramatic changes seldom happen in education (either with the curriculum or in practice). IT techniques continually infiltrate the system but by and large their 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 support or substitute not for radical changes in the curriculum, teaching, or classroom design.

Nevertheless educational policy makers in most countries try to look ahead, as for example "*The Engineer of 2020.*" But such reports are based on current outlook and current predictions [3]. They are convergent visioning. As Kourdi has pointed out the past is seen as a guide to the future [4]. The constraints or practices of the professional group hold sway and the result is convergent visioning [5]. Thus policies for higher education have been predicated on the belief that a highly qualified engineering and scientific manpower is required and that specified numbers of engineers and scientists are required to maintain and more especially develop economic wealth. Because engineering has caused new technologies to be developed it has also contributed to a growth in the number of specialisms on offer, and they in their turn require additional qualified personnel. Predictions about the future are often based on this model. It is the contention of this paper that the principal axioms on which this model is based no longer hold and that now is a time for divergent visioning.

The principal policy axioms and their effects.

In the western world policy since the end of the second-world war has been governed by the axiom that there is a continuing demand for highly qualified scientific and technological manpower. At the end of the second war as a consequence of the war time experience a need to raise the standards of education so as to improve the quality of the output was seen [6]. Specifically this was achieved by focusing on the scientific and mathematical bases of technology more specifically engineering. In short engineering has been seen to be an activity based on the applications of science on both sides of the Atlantic not with-standing the attention in the United States to the provision of liberal studies for engineers [7]. This consensus has in recent years been challenged by several reports and one major study in the US [8]. Challenging though they may be, such reports they remain within the convergent focus and will undoubtedly cause many minor innovations.

 To a large extent policy has been governed by the regularly reported predictions that there is and will be a shortage of engineers and scientists, and that the pool of students available to pursue these occupations is too small and declining in quality. In both the UK and the US this perception is taken to be correct and it is held that this will be detrimental to future economic prospects. Much attention has been paid to remedying this shortage particularly by focusing on the supply side of the equation. Michael, S. Teitelbaum a Program Director at the Alfred P. Sloan Foundation said at a conference on the U.S. Scientific and Technical Workforce "the supposed causes are weaknesses in elementary, secondary, or higher education, inadequate financing of the fields, declining interests in science and engineering among American students, or some combination of these. Thus it is said that the United States must import students, scientists, and engineers from abroad to fill universities and work in the private sector-though even this talent pool may dry up eventually as more foreign nationals find attractive opportunities elsewhere."[9]. But Teitelbaum went on to argue that such data that was available was weak and often misinterpreted [9b]. There was no evidence for a shortage of qualified personnel and in a submission to a sub-committee of the House of Representatives he said that, "*despite lawmakers being told by corporate lobbyists that R & D is being globalized in part due to shortages of scientists in the US no one who has studied the matter with an open mind has been able to find any objective data of such general shortages.* He concluded with the controversial view that, "*Federal policy encourages an over production of science professionals*." [10]. It has created its own system of vested interests. If the continuing attention to the shortage of students for STEM education is anything to go by this system is alive and well [11]. Of course it may not be true of other countries [12(a)].

Much the same could be said of the UK where since the 1960' there have been a series of reports lamenting the failure of schools to supply an adequate number of students to STEM courses. However, as a British commentator Robin Marris pointed out long ago, a point that has been reiterated by Lowell and Salzman in the US, labor shortages would be reflected in the market by higher wages [129b)]. Continuing alarms have been raised in the UK about the "brain drain" that

is, the exit of scientists and technologists to other countries especially the United States [13]. These worries have not afflicted Ireland where they are proud of the contribution that Irish trained engineers to developments in Silicon Valley and elsewhere. They are equally proud of the fact that Google, Hewlett Packard, Intel, Microsoft, and PayPal have made significant investments in Ireland partly because of their perceptions of the standard of education of the workforce.

Allied to the proposition that there is a shortage of scientific and technological personnel is the view that the supply of jobs is directly related to innovation. If jobs are being lost in one sector of the economy technological innovation will ensure that an equal number of jobs (and hopefully more) will be created elsewhere. It is with the challenge to this last view that this paper is primarily concerned.

Supporting data

Current data seemingly supports this axiom but it is often difficult to interpret. Some data reveals general shortages: for example in 2011 the Confederation of British Industry (CBI) reported that 40% of companies had difficulties recruiting people with science, technology, engineering, and maths skills. But it did not say at what level these skills were wanted [14].

Other data reveals specific shortages [12(b), 15]. A striking example of a specific shortage is that being experienced by the resurging nuclear power industry in the United States. "The persistent demand for nuclear power, coupled with mounting concern about safety, has exposed a dearth of advanced training programs in the increasingly complex skills required. During the three-decade hiatus in nuclear plant construction in the United States following the Three Mile Island accident in 1979, many universities phased out their nuclear engineering schools or merged them into other programs. Now demand for trained personnel is expected to rise. According to the Nuclear Energy Institute's 2010 Work Force Report, nearly 38% of workers in the US nuclear industry will be eligible to retire in the next five years. To maintain the current workforce the industry will need to hire 25,000 more workers by 2015. The US Bureau of Labor Statistics projects an 11% growth in the need for nuclear engineers in the period up to 2018" [16]. A parallel example comes from the UK where in respect of a large underground rail development in London (Crossrail) the contractor reported that it will require 1000 tunnellers. But there were only 500 tunnellers in the whole of the UK whose average age is 55 years. Unfortunately it did not say what qualifications were required [17].

More generally in the United States recent evidence on the demand for personnel seems to suggest that the pattern of demand is changing. So is there a changing pattern in the demand for personnel with technological skills?

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 % [18].

 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 Wadwha about an article that Wadwha had written in the September issue of the magazine [19]. 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 this was happening in the software industry. "After all the graduate is likely to have more up-to-date skills and will work harder." He went on to say that "if you listen to the heart-wrenching stories of older engineers" (who have become unemployed), "you learn that 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 ways described in the 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 roller-coaster. 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 Prism* said that often emerging technologies require far fewer workers [20]. 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 ask "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 his book *The Coming Jobs War* based on Gallup studies in numerous countries he comes to ten conclusions [21]. 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 almighty entrepreneurship. The investments should follow rare entrepreneurs versus the worldwide oversupply of innovation. Put another way, it's far better to invest in entrepreneurial people than a great idea"

(p 187). Elsewhere he argues that economies ride on the backs of small to medium-sized businesses. 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" (p 6). 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" (p6), which seems be somewhat contradictory since that does not presage a need for engineers. Support for 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 [22]. And, in respect of manufacturing the State of Minnesota has established a career and education pathways for a manufacturing and applied engineering worker that can bring them as far as middle management on the one hand and on the other hand an M.S. degree [23]. 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 [24]. 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

Workforce predictions, higher and third level education

Predicting the shape of jobs in the future is notoriously difficult and in the last fifty years has been made the more so by changing technologies. Nevertheless official or semi-official statistics do influence educational policy makers. There is no better example of this than recommendations in a recent study published by the National Governors Association in the US [25]. Among other items of information from individual States it uses the data from the US Bureau of Labor Statistics that is summarised in exhibit 1. It should be noted that 40% of those engaged in the IT industry in the US do not have a four year college degree. On the basis of such data and particular data from four states Erin Sparks and Mary Jo Watts who authored the report argue that post-secondary education needs to be much more aligned with the state's economic goals. Labor market data should be used to "develop courses that prepare students for high paying, high demand jobs" (p 3). The data presented is intended to show why states should cause the institutions of higher education to move away from their emphasis on a broad liberal arts

education to what in Britain and Ireland would be called a more vocational job oriented education. Evidently in the United States a liberal education versus vocational education debate will now ensue. Indeed, it has begun [26].

Top areas of job growth 2008 -2018
(ranked in order of potential growth)

Taking care of people
Making computers work
Taking care of business
Building and maintaining our Infrastructure
Teaching children
Designing things: solving problems
Keeping businesses running

Selling goods and providing basic services.

Exhibit 1. Adapted from - Top areas of job growth in the next six years simplified from Waldock, C (2011). *Closing America's Job Gap*. US Bureau of Labor Statistics. Cited in Sparks, E and M. J. Waits (2011) *Degrees for What Jobs? Raising Expectations for Universities and Colleges in a Global Economy*. National Governors Association.

Employers and their role

There is an assumption in the NGA report that employers know best, but do they? If this is the case then they have an obligation to accept that they have a social responsibility for an individual's development while in their care and a broader responsibility to help foster skills in employees that will guarantee them a basis for transferability.

 In the 21st Century skills and knowledge will become rapidly outdated. Individuals are likely to have to change jobs more quickly than they have in the past. They will have to be much more adaptable and flexible. At the same time employers will have to reduce this "*occupational transfer gap*" and enable employees to obtain new jobs in other spheres of knowledge. In the past in Britain and Ireland, employers have been unwilling to accept entrants whose qualifications are not directly related to the jobs they have [27]. They have been unwilling to accept that individuals have transferable skills that can be of value in any job. Coupled with the need to acquire a new work identity this can lead to the self-fulfilling hypothesis that employees' come to believe that they are only suitable for work in the areas for which they have been specifically trained. Is this "*occupational transfer gap*" real or imagined? This is an issue that Wadwha did not discuss and it is at the heart Professor Plotkin's complaint. Wadwha had asked "why are there so many middle-aged engineers in the ranks of the unemployed?" And, he had asserted that "most engineering professors don't understand the dynamics of the real world and they don't prepare their students adequately" (p 10). But he should be asked what is it that they together with the institutions of education have to do to prepare engineers for work at 50? It is a combined social responsibility that will prevent this wasteful use of resources.

Just as the *clichés* of 'adaptability' and 'change' are rapidly becoming a reality, so the platitudes about lifelong education will have to become equally real and individuals will have to take responsibility for a continuing engagement with learning throughout their lives and they will need employer support. The implications for the institutional structures of higher education and their relations with the world of work are profound, and this will require divergent visioning.

Personal Transferable skills

The model presented in the NGA report derives from a utilitarian view of education. The systems of education in the British Isles are largely based on this philosophy. In consequence they are based on a range of specialisms, and most students study one of these specialities for three or four years without reference to any other subject. There is no concept of the unity of knowledge. There is no such thing as a liberal arts curriculum. STEM subjects are accorded more status than the humanities in the eye of government. Universities have no unity of purpose other than that which is economic. The one similarity between the NGA report and British policy is that for twenty or more years the UK government has accepted employer complaints that graduates irrespective of the specialism studied are not suitably prepared for work in industry. But, and it is an important 'but', what they were said to lack were what came to be called '*personal transferable skills*' [28]. This point has been made by Lowell and Salzman in respect of the US [12(b)]. Remarkably the Personal Transferable skills found in UK documents have many similarities with those listed by the State of Minnesota Office of Higher Education. In exhibit 2, a table of the top skill requirements of Minnesota employers has been re-arranged and simplified to show that the affective domain and personal qualities are as important as the cognitive. They are not skills that separate the academic from the vocational but skills that any educated person would require. There is a general belief in the British Isles that these can be acquired from within a specialist study provided the teaching and learning is designed for that purpose. A working group of the Employment Department indicated four broad areas of learning that are important for equipping students for their working lives which they believed could be assessed [29]. Inspection of exhibit 3 shows them to be very similar to those listed in the Minnesota survey. Other comparisons with American reports were made in the same report.

Conclusion

However good, however poor the data several conclusions may be reached. First, it is no longer possible for educators, industrialists and policy makers to pay lip service to the need to educate for adaptability and flexibility and develop personal transferable skills. The curriculum needs to be evaluated in these terms. But it cannot be an evaluation that is independent of what happens before, and what happens afterwards. Higher education has to be seen to be a component of lifelong education that begins in the primary (elementary) school and extends through continuing professional development until retirement, even beyond. Industrialists have an obligation to participate in the promotion of an individual's career path even though it may take them from

Attributes (most frequent ratings of 'very important' by employers.

 Professionalism (punctuality, time management, attitude)
Self direction, ability to take initiative
Adaptability, willingness to learn
Professional ethics, integrity.
Verbal communication skills.

Most frequent ratings of 'not at all' or 'not very important' Last 5.

Advanced mathematical reasoning (linear algebra, statistics, calculus)
Technical communications
Fluency in a language other than English
Knowledge of specific computer applications required for the job
Application of knowledge from a particular field of study

Other

Capability for promotion and advancement
Creativity
Ability to work in a culturally diverse environment
Ability to work in teams
Written communication skills
Basic mathematical reasoning (arithmetic, basic algebra.
Critical thinking and analysis.
Problem solving, application of theory
General computer skills (word processing, spread sheets)
Knowledge of technology /equipment required for job

Exhibit 2. A re-arranged summary of the top skill needs of Minnesota Employers. Minnesota Office of Higher education. Minnesota measure. 2009. Report on Higher Education Performance.. Cited in full in Sparks, E and M. J. Waits (2011). *Degrees for What jobs/ Raising Expectations for Universities and Colleges in a Global Economy*. P27. National Governors Association.

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 leaders and as 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 3. 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 (1991) Cited in Heywood, J (1994). *Enterprise Learning and its Assessment in Higher Education* Technical Report No 20. Learning methods branch, Employment Department, Sheffield. (For a description of the Sheffield University work on Personal Transferable Skills see that report and also Heywood, 2005)

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that particular industry. Such development may be personal as well professional in the sense of acquiring technical knowledge and skills.

It is safe to assume that the world of work will continue to change, some dimensions at a much faster rate than others and that education will continue to adapt.

In the US there will be a debate about the relative merits of liberal education when compared with job oriented education. A central question relates to the role that engineering literacy could or should play in bridging the divide between these two apparently opposing philosophies.

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