Higher Education and Technological Disruption: Purpose, Structure and Financing

An Invitation Seminar October 9th 2017 at Dublin City University

Background paper

Alternative Models of Higher Education

John Heywood

Trinity College Dublin-The University of Dublin

heywoodj@eircom.net

Table of Contents

Preface

This study originates in papers presented to the Technological and Engineering Literacy and Philosophy Division of the American Society for Engineering Education at its annual conferences in 2010 and 2012 respectively. In the first, the curriculum circumstances in which engineering would be considered as a component of liberal education were considered. In the second, the impact of technology, automation and AI on the engineering and technological workforce was examined. It became clear that provision of continuous professional development programmes was inadequate to meet the increasing knowledge redundancy being experienced by engineers during their careers, and that some form of "permanent" education was required. A model comprising of two years basic high education followed by formal study either by distance learning or attendance at an educational institution at regular intervals throughout the person's life. Alan Cheville suggested that it could be financed by insurance and linked to the university initially attended when it could provide by distance or otherwise for the personal and professional needs of the individual. He also pointed out that a different understanding of the purposes of credentialing would be required.

It became clear that because of the general effects of technology on the workforce that the model applied to university education as a whole, and Professor Cheville asked me to deliver a lecture on the topic to academic staff at Bucknell University. He and I subsequently sought the help of Dr Charles Larkin (Trinity College Dublin) for advice on the financial aspects of the development of the model. We are grateful to him and his colleague Dr Shaen Corbett of Dublin City University for arranging this seminar.

I am extremely grateful to Dr Larkin for the insightful criticisms of this paper, and for the longstanding critical friendship of Professor Cheville.

John Heywood

September 2017.

Alternative Models of Higher Education

Abstract

Pragmatic decisions arising from arguments about the financing of higher education and the merits of student loans are likely to lead to step by step changes in present models of higher education which maintain a continuity with the past. It seems to be generally accepted that computer assisted learning will play a greater role than in the past, however there are also likely to be changes in the structure of programmes. For example, in the U.K. many present three year degree programmes are likely to be compressed into two years, and in the U.S some commentators argue that the community colleges will have to be revitalized. Characteristic of these developments will be their continuity with the past. In this scenario workforce forecasting will continue to be governed by perceptions that STEM graduates are in short supply. The curriculum will remain largely as it is, and the utilitarian philosophy that governs higher education will continue to value some subjects, particularly those that lead to higher earnings, over others especially those where the graduate premium is negative. Attempts to move students into more vocational courses are unlikely to succeed because of the low status they are perceived to have.

On the one hand this report has concerns itself with the ever increasing costs of higher education. Student loans are justified by a utilitarian philosophy that treats students and workers as commodities. Since there is a considerable differential between graduate and non-graduate earnings undergraduates should contribute to the costs of their education. These have increased considerably in the last decade, and contributed to rising inequalities. It is argued that the present system is untenable. It is noted that suggestions have been made for changing the structure of higher education programmes so as to reduce the costs.

On the other hand this report also concerns itself with impact of changing technologies on the workforce and in consequence higher education. It is argued that there is now a need to take "permanent" (continuing) education seriously and to view it as part of a system that begins in elementary school. The weaknesses of a purely utilitarian education are exposed and a case, based on the needs of both industry and society, for a basic higher education that is liberal is presented. Policy makers have to be persuaded that a utilitarian education that solely serves the economy is unbalanced. The "self" and "society" are of equal importance. A structure that combines a basic higher education with a "permanent" system of continuing education is proposed in which the basic higher education is funded by the state and the "permanent" education by the individual. It is suggested that individuals might provide that funding through dedicated insurance.

PART I

Tuition Fees, the Costs and Quality of Higher Education and its Structure

1.1. Tuition fees in the United States

In the United States debate about the financing of higher education, and in particular, student loans has led to fundamental questions about 'who' and 'what' is higher education for?

As a result of the banking crisis that occurred a decade ago, which most of us seem to have forgotten, the term "bubble" has once again became common parlance. Some writers considered that higher education was either in a bubble or about to become a bubble. In the United States tuition fees had risen by 274% in the years between 1990 and 2009 which was more than the price of any basket of goods or services. State funding at non-profit public higher education institutions has fallen dramatically during the last decade and prices have risen at twice the rate for four year private institutions [1].

Surprisingly, given that the labour compensation share in net income remained relatively static throughout the whole period, these rises did not give rise to a major debate about tuition fees given the importance attached by families to higher education [2]. To an extent this continues to be true, and again surprisingly, in "*Game of Loans*" Beth Akers and Matthew Chingos argue that typical borrowers of student loans face affordable debt burdens, that is they are able to repay them irrespective of the level of debt [3]. But while repayment may be feasible they point out that the fees market is dysfunctional since competition among colleges is having the effect of driving up tuition fees rather than down. Yet, if higher education is a market it makes sense. Those colleges that are perceived to have status will be in a position to up their fees, and those that wish to up their status will take fee levels to be some indicator of status. Colleges chase the richer students. This they can do by providing luxury facilities. The search for status functions in parallel with "curriculum drift", as for example every college must have a business school (with which to attract overseas students) [4]. It also functions in parallel with increasing emphasis by universities on research. The implications are profound for secondary education (see section 5.5).

Overall tuition costs increased most for those students who could afford them least [5]. No wonder that in the 2016 U.S., Presidential election young people supported Bernie Sanders and caused Hilary Clinton to state her intention of making in-state tuition free at public colleges and universities for all Americans whose families earn less than $125,000 a year. Similarly in 2017, in the U.K., where student loans have become a major issue, students appear to have come out in force to vote for left wing Labour Party leader Jeremy Corbin to the total surprise of the establishment. He proposed the abolition of student fees.

It is also argued that the fees dilemma arises from a particular philosophy, namely, that the purpose of college education is to serve the economic good. Since "free market" thinking dominates economic thinking all institutions should be run like businesses and compete with each other. In theory that would be all well and good but for the financialization that crashed the world economy in 2008.

Foroohar [6] whose book "Makers and Takers" gives an explanation the origins of that crisis paraphrased the views of Adair Turner [6a] to explain financialization thus, " Turner is saying that rather than funding the new ideas, and projects to create jobs and raise wages, finance has shifted its attention to securitizing existing assets (like homes, stocks, bonds, and such), turning them into tradeable products that can be spliced and diced and sold as many times as possible – that is until things blow up, as they did in 2008. Turner estimates that a mere 15 percent of all financial flows now go into projects in the real economy." Banks changed their role and created an economies based on debt. From the perspective of this study it is not only the impact on jobs of lack of investment but of the parallel impact of developments in technology on employment that are important.

Immediately, however, it is with the possibility that the financialization of education may have the same effect on higher education. Foroohar also takes this position. She writes, "Cryn Johannsen lays out in *Solving the Student Loan Crisis*. As she puts it, "students…are defined as consumers seeking out personalized education and training that will make them marketable," a concept that disconnects higher education from its value as a public good. Of course, American higher education was never completely devoid of mercantilism (for-profit business and trade schools have been around since the nineteenth century) and its virtually never been free; but payment for it was in the past split more evenly between families, the government, and philanthropy, and civic benefits were as highly valued as the economic ones (which, crucially, were seen as accruing to the nation, rather than just the individual) [7].

1.1(a) What is higher education for?

Foroohar points out that in the U.S. the possession of a graduate qualification is no longer a ticket to social mobility indeed it "can result in downward mobility" [8]. Robert Reich public servant and economist takes a slightly different view. "the demand for well-educated workers in the United States seems to have peaked around 2000 and then fallen as the supply of well-educated workers has continued to grow […] since 2000 the vast majority of college graduates have experienced little or no income gains at all […] To state it in another way, while college education has become a pre-requisite for joining the middle class, it is no longer a sure means of gaining ground once admitted to it" [p209, 9; 10].

Foroohar points out that between now and 2024 America will create 14, 000,000 jobs. They will nearly all require at least a two-year associate's degree, a consequence of which is that community colleges should become "the new high schools"- "a basic necessity for every American".

Support for this argument comes from data about the U.S. workforce [11]. About a third of new jobs up to 2020 will require no more than an associate degree but they will require something more than a high school diploma. These jobs have come to be called "New Middle Skilled" and contrary to Reich, it may argued from an earnings perspective that many of these jobs will bring workers into the middle class [12; 13]. (See also section 2.5).

Foroohar also argues that too many degrees from for-profit colleges in the U.S. are meaningless: her two examples are sports marketing and business administration! But, there are also those who argue that the quality of the for-profit college degree programmes are poor [14]. She goes onto argue that the higher education system should be reformed, and that it

should be recognized that the arts are as important as STEM subjects, hence the acronym STEAM [15]. This was argued by this writer at the American Society for Engineering Education in response to a report to the National Governors Association recommending a refocussing away from the liberal arts toward vocational studies in four-year public colleges [16, 17].

At the far end of the spectrum are futurists like Yuval Noah Harari [18] and Max Tegmark [19]. They contemplate a world in which AI and robotics have put us all out of work, one consequence of which is that we would all have to receive a basic income from the State. In these circumstances would higher education be redundant, or would it be a preparation for leisure, or the place where one finds one's personal identity? [20] If the latter, how would it be financed? That raises an additional question to Foroohar's "for whom is higher education for?" And, that is "What is higher education for?

1.2. Tuition fees in the U.K. The Graduate Premium

Charging fees is a recent phenomenon in the UK where most universities receive public funding. It followed legislation in 2004 at which time a cap was set at £3,000. The cap is now £9,000 soon to be increased. It has become universally charged. The legislation received support from both sides of Parliament but not the Liberal Party. Since 2010 there has been declining support for tuition fees and according to Rawnsley "Andrew Adonis (Labour) the self-described moving force behind the 2004 legislation says that "fees have become so politically diseased they should be abolished entirely" [21].

In response, it is argued that the size of the tuition fee has not put off the supply of applicants from the socially disadvantaged group. Indeed the numbers have increased. However, a report from the Social Market Foundation questions data from the Higher Education Statistics Agency [22]. The data presented by the Foundation shows that many of the disadvantaged groups targeted through widening access are also the groups who are most likely to drop out. The report does not consider student loans but it does say that financial constraints contribute to drop out, and Rawnsley makes the link with loans. It should also be noted that that another study reports an earnings gap of 10% (at the median) between graduates from higher and lower income households [23]. But the same study offers statistics to show "that a degree offers a pathway to relatively high earnings for a large subset of graduates from across institutions."

The principle behind the student loan is the graduate premium, that is, the difference between a graduate's earnings over a lifetime compared with a non-graduates. The Minister (Margaret Hodge) who made the proposal argued that it was approximately £400,000. But one research has put it at probably less than £100,000. This gives an annual premium of just £2,222 per year before tax. Kemp-King wrote that that is not enough to cover the interest on the loan [24]. It is important to note that the premium not only varies with institution attended but with subject as well. Medicine and dentistry are at the top of the scale, and subjects like sports science and the creative arts, at the bottom. It has also been suggested that the impact of technology on graduate jobs is likely to be profound which would affect the premium (see section 2.4 below).

When the system was legislated it was agreed that students would not start repaying the loan until they were earning £21,000. It was believed that most graduates would earn above that

sum, but that has not turned out to be the case. It is expected that many more graduates than was anticipated will not complete the repayments on their loans. The figure for those graduating in 2015 has been put at 70%.

An important finding of the Akos and Chingos investigation in the U.S. was that only a quarter of first year students can predict their debt load within 10% of the correct amount. This was put down in part to the complex deals they are asked to negotiate which change from year to year. In the U.K Ian King wrote "most graduates and their families still confuse the size of their debt with the far lower payments on it they will in reality face. Hence all the discontent as graduates fret about their ability to obtain a mortgage" [25]. Worrying about financing a mortgage is probably less important than worrying about financing a pension. Put the two together and the debt load begins to grow. Be that as it may the discontent is not likely to go away as students find that those who own the loan book can alter the rates of interest they have to pay on loans.

1.3. An alternative structure for UK degree programmes

One solution that has been put forward by a former minister for the Universities, John Denham is to compress the three year programme into two years. The three year university course in England and Wales 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 to 30% of the entrants. A private university in England that has gained a considerable reputation based its curriculum on a two year programme is the University of Buckingham. Its success will have influenced a recent Government decision to allow such accelerated courses. However, universities that do so will be allowed to charge a higher annual fee which might defeat the objective of reducing the costs of courses to students [26].

1.4 The quality of teaching

The high costs of fees have raised questions about the quality of teaching in both the U.K. and the U.S. The response of the U.K. Government has been to introduce a starred system of rating the quality of teaching that will impact on the fees a university is allowed to charge. There have been a series of articles in the quality newspapers about poor teaching which would not inspire applicants or their parents. For example:

"Students are getting a third class education" [27]

"Students taught one to one for only 26 hours in entire degree" [28]

The first article was a collection of comments from students in different universities who complained about the tuition they received. The second, is more important: it reports on a survey undertaken by two economists who undertook a study of contact hours between academic staff and students. Their purpose was to develop a quantifiable measure of the teaching resource provided by a university that could also provide a rough cost of tuition. It confirms the conclusion of Jenni Russell, the author of the first article, that students were being short-changed. They found that universities that charged more did not offer any more teaching. They write "unfortunately the ideology of independent learning the Russell group has developed results in students being taught in large classes with minimal feedback. This inevitably has consequences for the amount of work they undertake." Johnes and Johnes [29]

(cited by Holmes and Mayhew [30]), "reported that the cost of providing undergraduate courses in the U.K., is significantly less than the fees being charged and that undergraduate fees are being used to subsidize research".

That ideology is in stark contrast to the student-oriented view of the university propounded and followed by Newman in the nineteenth-century. In this respect the findings of a ten year study of Hamilton College are of interest [31]. This small private liberal arts college was the subject of a ten year study intended to find out "How College Works". The authors Daniel Chambliss and Christopher Takacs asked the question, "Can students get more out of college without spending more money?" This meant that they had to examine how the quality of college education could be improved without additional cost. The answer is surprising. They believed it could.

They found that the single most important thing in the quality of a student's education was to do with the way a college is organized to help the students with their relationships, and that went for the classroom experience as well. Relationships, "are the necessary precondition, the daily motivator, and the most valuable outcome. A student must have friends, needs good teachers, and benefits from mentors. A student must have friends, or she will drop out physically or withdraw mentally. When good teachers are encountered early, they legitimize academic involvement, while poor teachers destroy the reputation of departments and even entire institutions. Mentors, we found, can be valuable and even life changing……relationships are important because they raise or suppress the motivation to learn, a good college fosters the relationships that lead to motivation."

A large department in a large university is no different to a small college.

1.5 Grade inflation and the usefulness of some degree programmes

Criticisms of education are made at all levels. University education in the U.K. is criticised because in the last twenty years there has been strong grade inflation [32]. In an earlier period when the problem of grade deflation was severe in the U.S., it was explained that it was a function of the view that society took of grades in that particular period [33]. Milton and his colleagues also argued that teachers necessarily adapt to changing circumstances.

In the U.K. grade inflation has had the predictable effect of lowering the ceiling of jobs for which a degree is necessary. To put the picture in another way many graduates are employed in jobs for which they are overqualified [34]. But, their pay is more likely to be related to the job than to the degree. Therefore, there is an argument that students should be steered away from taking degrees that will result in lower earning's. But this is to take a strictly utilitarian view about what education is for. Britton and his colleagues write, "Over the period we observe in our data, the proportion of students taking subjects such as economics, law, and maths and computer science has reduced marginally, and more take subjects such as creative arts. It is too early to determine whether this is a trend, although Universities UK data do suggest stronger growth between 2002 and 2011 in business and administrative studies, biological sciences, education, social studies and creative arts and design and rather weaker growth in law, mathematical sciences and computer science, to name but a few. Graduates who study the creative arts, for example, tend to earn less and so over time we might be concerned that these shifts will bring down the graduate earnings premium. What is not clear is the reason for these changes in subject mix" [35] Apart from the fact that students want to

study these subjects they suggest that some universities offer more lower cost courses since fees do no vary by subject. This they argue should be taken into account when reckoning the public subsidy for education. Clearly they have been defeated somewhat because students do not follow the rational expectations model that economists have of the person. Students use rule of thumb heuristics in a situation of information asymmetry. The model supports those who argue, that in any event, many undergraduates are not suited to higher education and would be better suited to vocational courses.

1.6. Questions about the purposes of higher education

So, taken together with complaints about teaching we come back to the same question "what is university education for?" Students and their parents and probably most taxpayers are unlikely to be satisfied with the response given by the head of a humanities faculty in a Russell group university to questions about student complaints. She replied to Andrew Rawnsley with a sigh," It's our fault." 'We've not being good at making the students understand that teaching is not what we are here for.' So what are universities for?

In the absence of an answer to this question the system is likely to change, as it has done in the past, that is, in small steps that maintain some continuity while at the same time allowing business methods to dominate policy making. Given all the factors, but particularly that of student loans at a time when parental incomes are roughly static, the likelihood of the time span of programmes being generally reduced (.e.g. 2 years in the UK, and 3 years in the US) is great, although there will be much resistance to it. Furthermore, perceptions about what is required for the world of work will focus on trying to make individuals take vocational courses that provide a higher remuneration than they would otherwise get from pursuing degree programmes with less rewarding outcomes. This assumes that things will remain pretty much as they are: technologies will put people out of work but new technologies will provide an equivalent number of jobs to those that have been lost. But, this is an assumption that is being challenged by several authorities including leaders in technology.

1.7. Conclusion to part I

Apart from issues of inequality, arguments about student loans in both the U.K. and the U.S have led to questions about the structure of higher education, the quality of teaching, the content of the curriculum, and the irrelevance of certain degrees to the economy which students persist in taking. Some commentators suggest there should be more non-degree level vocational education beyond high school, and more students should be directed to this route. At a more fundamental level the changes that are taking place lead to questions about the purposes of higher education-"For whom?" and "for what?"

In this utilitarian system of education the question arises as to whether this ideology is supported by changing patterns in the workforce as it responds to changing technology. This issue will be considered in part II.

Part II

Technology and the Changing Structure of the Workforce

2.1. Impact of technological forecasting on educational policy

Workforce forecasting is notoriously difficult, and distinguishing myth from fact is sometimes problematic as Michael Teitelbaum has shown [36]. The apparently quite simple task of categorizing a particular 'job' can be very difficult. Because the assumptions made by educators, industrialists and researchers may differ the task of interpretation may be as difficult as biblical exegesis!

In the U.K. there has been a fairly consistent belief during the last seventy years that there is a shortage of qualified scientists and technologists [37]. Estimates made of the numbers of qualified scientists and technologists since 1945 have helped determine future policy in higher technological education. Except for one, these reports held that there was a shortage of such personnel. The exception in 1961, caused much controversy. It said that supply and demand would be in balance by 1965 [38]. The next report in 1963 focussed on shortages, particularly of technologists [39]. The Committee on Scientific Manpower doubted whether employers' statements about their future requirements could be regarded as fully valid. They thought that employers of mechanical engineers should be employing more qualified staff if they were to expand in the next decade. Similar debates have taken place in the United States often accompanied by employer lobbying for funding or visas to offset shortages. They often won [40].

In the U.S., Charette uses a report from the Georgetown University Center for Education and the Workforce to illustrate one of the difficulties of workforce forecasting, in this case unforeseen events [41]. The report predicted 2.4 million STEM job openings in the United States between 2008 and 2018 with 1.1 million newly created jobs, and the rest to replace workers who retire or move to non-STEM fields; they concluded that there would be roughly 277,000 STEM vacancies per year. Charette points out that the study did not fully take into account the effects of the downturn that occurred with the Great Recession. The jobs increase forecast for 2010 did not happen, instead there was a loss of 370,000 science and engineering jobs.

A heading for an article on the front page of the *Wall Street Journal* of October 13th 2016 read, "Tech Boom Creates Too Few Jobs" with the sub-heading, "Dashed Employment Promises of the 1990's fuel Donald Trump's Political Rise". Among several items in a long article we read, "photo-sharing service Instagram had 13 employees when it was acquired for $1 billion by Facebook in 2012".

According to Charette about 15 million U.S. residents hold at least a bachelor's degree in a STEM discipline, but three-fourths of them-11.4 million-work outside of STEM.

Charette found that there was "an extraordinary amount of inconsistency" among the hundreds of reports, articles and papers published during the last sixty years. This is consistent with this writer's finding. Yet, as Teitelbaum has shown, politicians have consistently responded positively to views that the U.S. is short of scientists and engineers

[42]. But Charette argues that this response causes money to be diverted into solving this problem rather than solving the problem of shortage of STEM knowledge that exists in the population as a whole. "We should be figuring out how to make children literate in the sciences, technology and the arts to give them the best foundation to pursue a career and transition to new ones" [43]. Charette does not consider the problem of specific shortages.

2.2 Specific shortages

The phrase "specific shortages" has at least two meanings. The first applies specifically in the U.S. and relates specifically to "speciality" or "guest" workers. These are workers who have been brought into the United States on H-1B visas. These visas were instigated in response to successful lobbying by employer led groups. They were "justified on grounds that employers requiring scientists, engineers, computer and IT workers were facing debilitating "shortages" of qualified hires and therefore impeding their ability to compete internationally" [44]. A person seeking such a visa had to possess a bachelor's degree. The legislation came in at a time when the booms that were used to justify these visas came to an end!

In relation to the workforce Teitelbaum identified five rounds of alarm/boom/bust since World war II, most lasting for a period of between ten and twenty years. It is difficult to infer from Teitelbaum's data that there was a general shortage of qualified STEM workers [45].

The other meaning of "specific shortage" is not very different. It relates to specific 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 [46].

Other data reveals specific shortages [47, 48]. A striking example of a specific shortage was that of 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" [49]. 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 [50].

More generally in the United States some evidence on the demand for personnel seems to suggest that the pattern of demand is changing at all levels of skill including professional work, as the next section on engineers suggests.

2.3. Changing patterns in employment prospects in engineering. Toward an alternative model of higher education

Much of the data used in current commentaries was derived several years ago because that is the way data is collected (e.g. census data usually collected at the end or beginning of a decade).

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% [51].

G. Paschal Zachary writing in *IEEE Spectrum* said that often emerging technologies require far fewer workers [52]. 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.

Related to employment in the software industry is a comment in 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 [53]. 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".

Wadwha continued "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". It seems there is a serious unemployment problem among middle aged and older engineers in some sectors of the US.

While Professor Plotkin questions whether or not anyone would want to work in an industry that treats its workers in the way described by Wadwha the way industry employs people is changing dramatically, and some may say with the Professor for the worse.

For example, 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! A couple of years later Charette went further [54]. He wrote, "The nature of STEM work has also changed dramatically in the past several decades. In engineering, for instance, your job is no longer linked to a company but to a funded project. Long term employment with a single company has been replaced by a series of *de facto* positions that can quickly end when a project ends, or the market shifts [55]. To be sure, engineers in the 1950's were some-times laid off during recessions, but they expected to be hired back when the economy picks up. That rarely happens today. And unlike in decades past, employers seldom offer generous education and training benefits to engineers to keep them current, so out-of-work engineers find they quickly become technologically obsolete".

Several fundamental questions arise. It seems clear that industry believes that the costs of education and training should be borne by society in the form of educational institutions (public or private), and the state acting on behalf of society believes that the student should pay the costs of higher education. Two questions arise. First, "What responsibility, if any, should industry have for the education and generic training of the people it employs? Second,

"What responsibility does society acting through the State have for the education and development of the individual at the end of their secondary (post-primary) education?"

In relation to Wadwha' remarks and the purposes of higher education, Charette's comment raises the question as to, "how long engineers can make such changes before they become unemployable?" Wadwha's response to Professor Plotkin is an indirect answer with a constructive outcome. He cites the metaphor of a roller coaster and argues that universities need to prepare students for that ride so that when the need arises they are able and interested to change jobs.

Irrespective of the extent of middle aged engineer unemployment or the employment of young engineers for a short period of time it is clear that in terms of knowledge redundancy engineers require spells of "retraining". This term is used in preference to continuous professional development (CPD) since CPD implies knowledge acquisition in relation to current employment. In some cases engineers may well have to seek employment in activities (jobs) that are at a cognate distance from the jobs they currently have. This implies a need for continuing professional and personal development (CPPD), a term that is not currently in use. It implies that all higher education is in part about providing a base for "permanent" education (a term favoured in the 1960's), and raises questions about the responsibility for the base education, and the subsequent continuing education to which it is linked.

Heywood suggested that the basic higher education should be of two years duration. He did not envisage three years being compressed into two as proposed by Denham and operated by institutions such as the University of Buckingham because he thought it would be necessary for individuals to top up their learning at regular intervals throughout their careers.

Cheville proposed that this should be funded through insurance. He thought that the policy might be linked to the higher education institution that the person first attended for purpose of credentialing. It was unrealistic, he argued, to place the responsibility for CPD on the individual particularly those individuals working in the GIG economy. As individuals age they do things that society needs such as creating families and seeing they are educated: participating in the work of charities, and contributing to the work of local and central democratic government.

He argues that nations have created education systems that are based on hierarchical structures of knowledge that may or may not be "true" or "relevant" in the context of changing and economy and technology. It forces many young persons into thinking about careers before they need. Add internet learning into the mix and the need for fixed discrete periods of learning disappears.

Cheville contrasted the current mortgaged based method of financing higher education via student loans with the insurance based model that is suggested by the changes on the workplace and advances in technology, particularly robotics and AI. They create the perception of an investment rather than the yoke of a loan. In the latter, small payments rather than large payments are made. Economically the alternative model has the possibility of bringing in a new pool of talent.

He also believed that the system should provide multiple pathways to success. Cheville pointed out that alternative structures of higher education would inevitably involve changes

in attitudes to credentialing [56]. This seminar originates in problems related to financing different structures of higher education.

Beyond engineering the impact of technology on the professions has been described by the Susskind's Father and Son [57].

2.4 The impact of technology on professional work

The Susskind's, point out that while the major impact so far of the digitisation and automation of tasks has been on unskilled, low skilled workers and low wage occupations [58] it is now beginning to impact on the jobs done by the lower middle and professional classes. The Susskind's conclude that "increasingly capable non-thinking machines will displace much of the work of human professionals." Young graduates know that this is the case, and some are worried. A survey of 8.000 college educated young professionals from 30 countries revealed that 51% thought they would need to be retrained to stay relevant in their positions, and 40% thought that automation would threaten their current job because there would be less demand for their skills, while 53% said automation would make the workplace more impersonal. But those who had technological skills thought that automation would increase the number of jobs open to them [59].

In contrast the pessimistic forecast suggests that "an increasing number of professionals must be absorbed in a decreasing range of types of task (namely, those in which professionals still have the advantage). In short, it will become ever more difficult, as time passes and machines become increasingly capable to ensure that there is enough reasonably-paid employment for professionals" [60, p290]. The Susskind's who made this prediction were very clear that they were, "not predicting that the professions will disappear over the next few years. We are looking decades' ahead […] and anticipating incremental transformation and not an overnight revolution" [61, p219]. One step in this direction is the development of co-robotics in which individuals and robots work together in situations where the individual holds the comparative advantage. Beyond that are substantial improvements in machine reasoning

It is concluded that the direction of change in professional work and the professions will necessitate changes in the structure of education that professionals receive since, like engineers, they too will need life-long education, and some may need to take non-cognate jobs. So to, will many of those in the "new middle skill jobs".

2.5 The "new middle skill jobs"

Autor would appear to be a little bit more sanguine for the reason that it will take a very long time to overcome the limitations of current technology to accomplish non-routine tasks [62]. He believes that "new middle skill jobs" will arise that will replace traditional middle class jobs, and that just as automation in the 1950's did not create unemployment the same will happen now. But this is to rely on what has happened in the past. The pessimistic view takes the position that changes in technology are much more rapid than they have been in the past, and that difficulties with machine learning will be overcome more quickly than is currently judged.

Autor's [63] benign view of the impact of technology on jobs continues to prevail. Brynjolfsson and McAfee had argued earlier that while jobs are being destroyed new jobs are being created for which new skills are required [64; 65; 66]. But it depends on having the

right skill set. Otherwise they caution, "There's never been worse time to be a worker with only 'ordinary' skills and abilities to offer because computers, robots, and other digital technologies are acquiring these skills and abilities at an extraordinary rate." [67, p 11]. These middle skill tasks will, to cite Autor, "combine routine technical tasks with non-routine tasks have the comparative advantage: interpersonal interaction, flexibility, adaptability, and problem solving" [68]   Autor cites Holzer to the effect that "new middle skill jobs" are growing rapidly even in technical production and clerical occupations [69]. The Brookings Institute suggests that augmented reality (AR) can bridge the manufacturing skills gap. They also suggest that it can be used to train workers in new skills which may help reduce the skills gap [70].

Such views are strongly supported by the O.E.C.D. They write , "To seize the benefits of technological change, economies need ICT specialists, workers who can code, develop applications, mange networks and manage and analyse Big Data, among other skills. These skills enable innovation in a digital economy to flourish, but also support the infra structure that firms, governments, commerce, and users rely on [71]. However, besides these experts, digitalisation also calls for all workers to have a relatively high minimum level of ICT skills, even those on low skilled jobs. For instance, this is the case for blue collar workers in factories that are entirely automated or waiters having to take orders on iPads" [72].

Matthews the editor of *ASEE Prism* 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 [73]. 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 a need for engineers. Support for this view will be found in Washington State's Assessment of Education Credentials and Employer Needs programme [74]. 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. And, in respect of manufacturing the State of Minnesota has established career and education pathways for a manufacturing and applied manufacturing workers that can bring them as far as middle management on the one hand, and on the other hand an M.S degree [75].

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 [76]. In the UK this would be called technician level education. But, 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.

In the U.S. "New Middle-Skill Jobs" that provide the new skill sets have been estimated to provide one third of new job openings between 2010 and 2020 [77]. Many of them are not in technical occupations as exhibit 1 shows. Moreover, some of these jobs produce greater life time earnings than for graduates [78, 79]. While more than a high school diploma is required for many of these jobs, a degree is not, and in consequence some persons can find the route to these jobs is at the same time a route of social mobility. The most common educational routes

to success are via associate degrees and post-secondary certificates in Community Colleges. Thus, Foroohah argues that community colleges need to be revitalized [80]. Similar arguments are made about the technical colleges in England [81]. Industry is also becoming increasingly interested in offering its own courses and certificates, as for example Boeing and Microsoft. Computer software engineers, aircraft mechanics, electricians are among the high earners [82]. Career Vision concludes its pamphlet on these jobs that, "Since lifelong learning is a characteristic of work today, a middle skill job can also set the stage for further education and even greater career progress" [83, 84].

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 but ranked in order of demand from Waldock, C. 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.**

A finding that distinguishes Ireland from other nations is the youthfulness of its population. Acemoglu and Restrepo show that countries that are ageing rapidly are those that have been at the forefront of the development and utilization of industrial robots (fully autonomous machines that do not require a human operator), and have also been responsible for the growth these countries have experienced [85]. At the same time in another paper Acemoglu and Restrepo find that thus far the effects of robots in the US "are most pronounced in manufacturing, and in particular in industries most exposed to robots; in routine manual, blue collar, assembly and related occupations, and for workers with less educational qualifications" [86]. They did not find among any of the occupation or education groups positive and offsetting gains in employment. This raises the general question, "If the level of education among these groups is raised will there be sufficient jobs to offset the unemployment created?"

2.6 Conclusion to part II

Workforce forecasting is notoriously difficult. Nevertheless governments of differing political hues are persuaded by such forecasts, and the pressure from lobby groups to base their strategies for higher education. The belief that there is a shortage of STEM graduates has diverted resources away from the more pressing problem of the engagement of the school population in general and technological literacy. At the same time shortages of specific types of technologist do occur which are difficult to forecast. But, overall the pattern of demand continues to change. During the last decade firms, even those in silicon-valley have come to employ fewer workers. For reasons of renumeration and rapid changes in knowledge technological firms may prefer to employ younger people leaving a cadre of unemployed middle-aged engineers. At the same time many individuals will have to change career paths on more than one occasion during their working lives. As the patterns of work change so the need for continuing professional development becomes an imperative. A permanent system of education will require changes in the structure in all the sub-systems of education.

Changes in technology and automation have made a considerable impact on unskilled and low skilled work but they are beginning to impact on lower middle class jobs. The prevailing view is that as jobs are lost other technologies will replace them: but, there is some evidence that some jobs are irretrievably lost. The optimistic view is that all will be well if workers are re-skilled but this has implications for the institutions that provide for re-learning. It is argued that the fear of robots is misplaced. In many areas the human has the advantage over the robot which will be increased in some circumstances when the human works in collaboration with a robot(s). In any event changes take place in the very long term because there are so many difficulties to be overcome with machine learning. The pessimistic view argues that these assumptions are based on previous experience, and the assumption that the past acts as a guide to the future no longer holds [87]. They are the result of convergent visioning [88]. Rapid changes in technology and the probable development of new materials are likely to speed up the rate of technological change.

At the same time a substantial class of "new middle skill jobs" is emerging which will not require a graduate level education but something in between that and a high school diploma. Examples of these "middle skill" jobs are given in, "Aligning Technology and Talent Development" just published. It shows the competencies required from two year community college courses, and those required from 4 year degree programmes in the same area [89].

Part III

Education and Employment

3.1 Technological employment

Since the 1950's in the U.K. there has been a continuing flow of criticism of the formal system of tertiary education. It caused the Ministry of Education to develop a sub-system of technological education that would provide graduates specifically for industry. For a number of reasons this system failed. The nine colleges selected to undertake this work became universities having demonstrated that the courses they implemented were degree standard.. One reason for their failure to deliver a curriculum that was different to those offered by the universities was the lack of a theoretical (philosophical) framework that would enable the embryo ideas that existed to be developed into a full bodied curriculum. For example, the idea of "integration", that is the linkage became academic study and the industrial training too which it was supposedly linked. The possibilities of what could be achieved were not understood, neither was the role of experience in learning [90; see also appendix for extended commentary].

By the time *The Taxonomy of Educational Objectives* was published in the U.K. (1964) the colleges knew they were going to become universities [91]. *The Taxonomy* might have raised the level of discussion to the extent that an educational framework may have emerged. It did have a profound effect on the development of Engineering Science at the Advanced level of the General Certificate Education, an examination used for entry to university [92]. But its developers found that the categories of the taxonomy did not completely meet their needs particularly in respect of creativity. An attempt to task analyse the work done by engineers in a firm in the aircraft industry with the purpose of developing a taxonomy of training objectives showed that any such taxonomy should include categories of communication, diagnosis, and management [93]. In the forty or so years since that study industrialists have continually complained about the poor communication skills of graduates. While universities have taken steps to develop communication skills in engineering courses James Trevelyan, as a result of analysing the practice of engineers, concluded that these courses did not meet the needs of industry. He found the key work done by engineers was "technical liaison" in which a form of communication is a priority skill [94].

An evaluation among managers and supervisors of the British Steel Corporation who had attended in-company training courses showed that the most important need was for communication skills.

Bill Humble, a senior training officer with the company, who with this writer undertook that study, also analysed management and supervisory tasks using the categories of both the affective and cognitive domains of *The Taxonomy* and showed the importance of skills in the affective domain [95]. (In this text the affective domain is taken to embrace values, beliefs and behaviour, and encompass those qualities that are commonly thought to belong to the rather loose concepts of social and emotional intelligence [96]). That skills in both domains are required by managers and supervisors is illustrated by another study undertaken by Humble who observed managers and workers in situations that were to some extent

confrontational. His partially developed categories are shown in exhibit 2. Notice, that he includes a category of "adaptability" and defines what it means. This demand for adaptability, whatever it might mean, continues to be made. He defines a category of "control" in terms of the management of people. At the present time there is surely need for a category of "control", not only of people, but of technology and ourselves. It is not surprising that he should have included a category of "relationships", since he had had to deal with conflict situations. Recently this category has been expressed as the ability to work in teams.

The ability to adapt involves
The ability to perceive
- (i)   That organizational structure and formal, informal relationships, value systems and languages and therefore its needs, knowledge of the technical, human and financial aspects of the system or situation.
- (ii)   The different thought processes involved in the solution of human or technological problems.
- (iii)   Our own self and attitudes.

The ability to control involves
1. Knowledge of
   - (i)   How the skills of those who have to be controlled should be used.
   - (ii)   His or her requirements in relation to needs for communication, competence and excellence.
   - (iii)   What people ought to be doing.
   - (iv)   Whether or not they are doing it effectively
   - (v)   How to create a climate in which jobs will be done effectively.
2. The ability to make things happen.
3. The ability to be able to discriminate between relevant and irrelevant information
   Etc.

The ability to relate with people involves
1. Knowledge of rights, responsibilities and obligations.
2. Knowledge of ways of thinking (determinants of attitudes and values) of people in all parts of the organization.
3. Ability to understand when action in the key environment is right and acceptable in those circumstances (i.e. to understand the effect of his or her behaviour on a situation).
4. Ability to be able to predict the effects of his or her behaviour and that of others on a situation.
5. Ability to create the feeling that the job is important.

Exhibit 2. W. Humble's partial derivation of a taxonomy of industrial objectives from a typical works (steel) situation in which managers and workmen were in some degree of confrontation. Circa 1966.

It is of interest to consider Humble's categories in the light of the subsequent development of Sternberg's theory of intelligence [97]. Sternberg defined intelligence as a "mental activity directed toward purposive adaptation to, selection and shaping of, real world environment relevant to one's life". This is very much about individual's controlling and directing themselves. Given the *Oxford Dictionary's* definition of management as "direction and control" it is about self-management.

Comparing Humble's categories to the categories that Sternberg derived from the study of the definitions that lay people and experts gave of intelligence shown in exhibit 3 [98] suggests many similarities, and this true of the many lists of objectives (abilities) drawn up to indicate the skills that need to be learnt.

Examination of the complaints of industrialists during the succeeding years show that, while they do not use the term affective, the skills they seek relate as much to the affective domain as they do to the cognitive if not, more so. It is by no means clear that academics understand this to be the case.

As will be seen industrialists have made similar complaints about graduates in general, and governments have responded.

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.
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.
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 judgments, 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 3. 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 intelligence whereas lay persons stressed interpersonal competence in a social context. In R. J. Sternberg (1985) *Beyond IQ. A Triarchic View of Intelligence***. Cambridge University Press.**

3.2 The response of policy makers to industrial complaints

In 1989 response to complaints by industrialists about the performance of new graduates the U.K .Employment Department (=U.S. Department of Labor) initiated a programme designed to encourage all universities to develop the skills that industry claimed it required. It was called the Enterprise in Higher Education Initiative (EHEI), and the skills it developed were called the skills of enterprise learning. As part of its work the programme supported a research and development unit at the University of Sheffield that sought to clarify what these skills were. It achieved this goal by analysing hundreds of adverts for graduates in the national press and came up with the model shown in figure 1 [99]. It will be seen that it has nothing to do with knowledge content but is related to the cognitive and affective behaviours that graduates should bring to their work. They called them '*personal transferable skills*'.

Universities in the U.K. were supported for five years to develop these skills within all subjects.

The Employment Department wanted universities to assess these skills and the committee that was convened to develop assessment drew up the list of areas of learning that are important for equipping students for their working lives (exhibit 4). The influence of the Sheffield study will be apparent as will the similarities with the views of intelligence expressed by lay persons and experts in Sternberg's study (see exhibit 3). The Employment Department also funded the development of a personal competence model by the Management Charter Initiative. The model is shown in figure 2. Once again it is possible see elements of the categories developed by Humble.

The U.S. Department of Labour was also concerned with secondary education as a preparation for the world. It considered that a high school diploma was worthless and

proposed a high school curriculum (SCANS curriculum) suited to the world of work in a report published in 1992 (The SCANS report) [100]. Exhibit 5 shows the work place competencies and foundation skills around which the curriculum should be developed. It should be noted that systems (thinking) is one of the categories. Of particular interest are the examples of how these skills could be integrated into the curriculum that are given in the report. Some schools did offer a SCANS type curriculum but it was not an idea that took off. Might that be because it came from a Department of Labor? In the U.K. the Employment Department failed to maintain significant initiatives that it made in schools (e.g. The Technical Vocation Education Initiative- TVEI).

TRANSFERABLE
PERSONAL SKILLS

- a developmental model
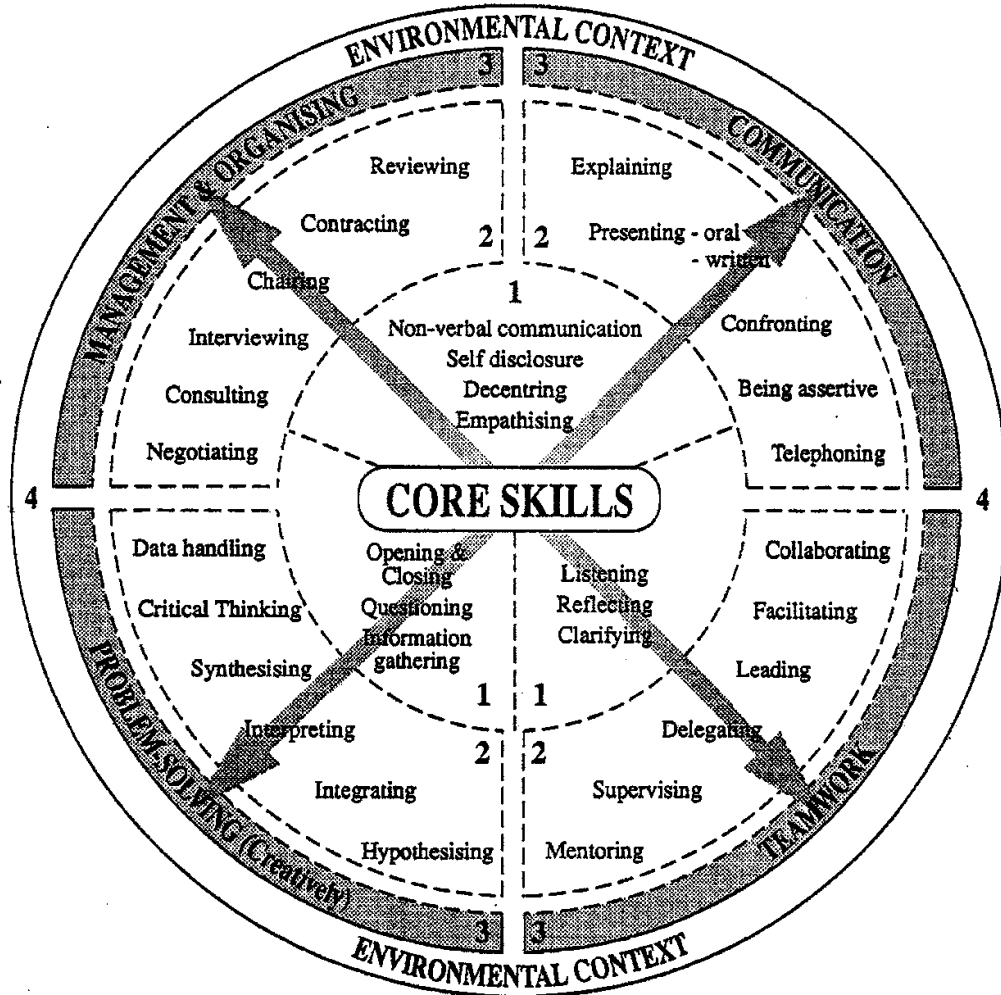
Zone 1 Core Skills
Zone 2 Group Skills
Zone 3 Skills in a Organisational Context
Zone 4 Environmental Context

Increasing Complexity of Skills

Figure 1 Personal Skills Chart developed by the Personal Skills Unit of Sheffield University 1990.

Clusters of Personal Competence:

PERSONAL COMPETENCE

1. Planning to Optimise The Achievement of Results

2. Managing others to Optimise Results

3. Managing Oneself to Optimise Results

4. Using Intellect to Optimise Results

Dimensions of Personal Competence:

1.1 Showing Concern For Excellence
1.2 Setting and Prioritising Objectives
1.3 Monitoring and Responding to Actual Against Planned Activities

2.1 Showing Sensitivity to the Needs of Others
2.2 Relating to Others
2.3 Obtaining the Commitment of Others
2.4 Presenting Oneself Positively to Others

3.1 Showing Self Confidence and Personal Drive
3.2 Managing Personal Emotions and Stress
3.3 Managing Personal Learning and Development

4.1 Collecting and Organising Information
4.2 Identifying and Applying Concepts
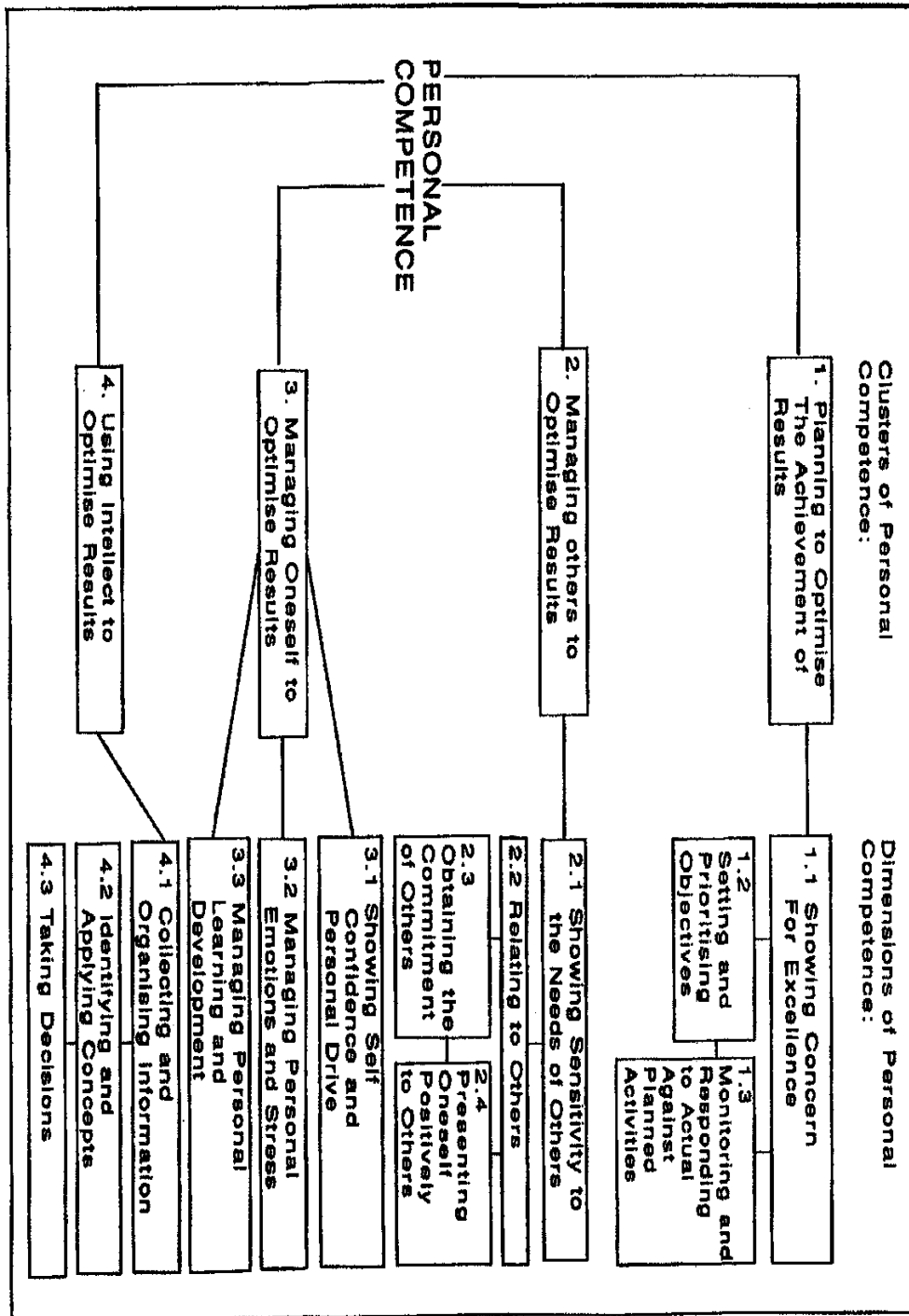4.3 Taking Decisions

Figure 2 The Personal Competence Model developed by the Management Charter Initiative funded by the Employment Department *Personal Competence Project* Summary Report 1990 Standards Methodology Branch, Employment Department, Sheffield,

The personal transferable skills have many similarities with those listed by the state of Minnesota Office of Higher Education. A re-arranged and simplified list of the top skills required by Minnesota employers is shown in exhibit 6. It can be inferred from this list that the affective domain and personal qualities are likely to be as important as the cognitive. They are not skills that separate the academic from the vocational, but skills that any educated person would require and that liberal educators profess to develop. The Employment Department believed that these skills could be developed within a person's specialist study provided that learning was designed for that purpose, and the Sheffield Unit showed how this might be done. But it was also argued that, (a) some special provision should be made for separate study in what might be called organizational behaviour and behaviour in organizations, and (b) that university programmes should be designed to meet the developmental needs of students, a proposal that had the theories of Perry [101], and King and Kitchener in mind [102].

In the U.S. in a challenging report for the National Governors Association in 2011 Erin Sparks and Mary Jo Waits who described the Minnesota Study listed above also described similar work in other States. They argued that the States should take much more notice of the comments of employers than they had in the past. More dramatically they proposed to the National Governors Association that the Governors' should make a radical change in direction, and redirect their support away from traditional four year programmes of general education toward the provision of courses that would "*better prepare students for high paying, high demand jobs*" [103].

This substantial paradigm shift briefly reignited the debate between two opposing philosophies about the relative merits of liberal/general education on the one hand, and on the other hand, job-oriented (vocational) education [104]. The report should have provided an opportunity to open a fundamental debate about the aims of education in a technological age that would spread internationally. That did not happen, and decisions world-wide continue to be made that are based on the prevailing utilitarian philosophy. (In particular they ignore research in pedagogy and curriculum). But, in essence current discussions about engineering education revolve around this debate. Its resolution in the light of technological change is also its relevance to higher education *per se*.

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 to apply the styles learnt appropriately to the solution of problems.

Exhibit 4. 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.

Workplace competencies	Effectively workers can productively use
1. Resources	They know how to allocate, time, money, materials, space and staff.
2. Interpersonal skills	They can work in teams, teach others, serve customers, lead, negotiate, and work well with people from culturally diverse backgrounds. They can acquire and evaluate data, organize and maintain files, interpret and communicate, and use computers to process information.
3. Information	They understand social, technological, and organizational systems, they can monitor and correct performance, and they can design or improve a systems.
4. Systems	They can select equipment and tools, apply technology to specific tasks, and maintain and troubleshoot equipment.
5 Technology	

Foundation skills	Competent workers in a high performance workplace need
1. Basic skills	Reading, writing, arithmetic, and mathematics. Speaking and listening.
2. Thinking skills	The ability to learn, reason, think creatively, make decisions and solve problems.
3. Personal qualities	Individual responsibility, self-esteem and self-management, sociability, and integrity.

Exhibit 5 The SCANS competencies (SCANS Secretary's Commission on Achieving Necessary Skills- Competencies and Foundation Skills for Workplace Know-How). *Learning a Living: A Blueprint for High Performance.* **Washington, DC. U.S. Department of Labor.**

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 items

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
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 theory
General computer skills (word processing, spread sheets)
Knowledge of technology equipment required for job.

Exhibit 6. A re-arranged summary of the 20 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 the Global Economy.* **P27. Washington. DC National Governors Association.**

3.3 Conclusion to part 3

Comparing all these lists, there are others [105], with the views of the laymen and experts categorised by Sternberg, it seems that everyone is seeking "Intelligent behaviour". Since the same complaints occur again and again during a sixty year period it is reasonable to ask, why nothing has been done about them? Is it that the curriculum might be doing its job? Or, are there other more significant factors at play?

A major reason is that education is not governed by the search for truth but by cherished beliefs that are deeply embedded in particular culture. That this is so is illustrated by Sir Charles Carter in a critical review of the recommendations of the Robbins Report on Higher Education in the U.K written twenty years after the event in 1983 [106]. The idea that education like any other area of knowledge is open to examination is almost *verboten*. In these circumstances changing an education system requires substantial disruption. It is proposed here that rapid changes in technology and AI will cause that disruption. Irrespective of whether it is in the short or long run it behoves the community to consider the possibilities so that it can react to such change.

Evaluation of one major attempt to change a system in the 1960's shows that any proposal has to be plausible to those who have to make the change which means that there has to be prior knowledge of the proposal that has to have been debated (see appendix). As Nodding's pointed those who seek change must do so within an adequate philosophical framework [107].

Both directly and indirectly these two lists draw attention to the need for employees to be adaptable and flexible by which is meant the ability to learn a new job when the one they are in becomes redundant. What was a cliché has become a reality for employees, but it brings with it responsibilities for employers. Continuing personal (professional) development will have to become a *sine qua non,* and a responsibility of both employee and employer so that employees have the skills necessary for transfer to a wide range of occupations. For this they will require a wider and more unified form of knowledge than in the past as will be argued in part IV.

Part IV

Adaptability, Transfer of Learning and Liberal education

4.1 Introduction

Philosophy contributes to the aims of education in several ways. In the activity of screening it helps sort out contradictions in the aims proposed [108], and philosophy helps clarify the meaning of terms used in statements of aims. At a more profound level ideologies of the curriculum derive from theories of knowledge. Michael Schiro has identified four such ideologies that have been used to support the school system in the United States [109]. There are others as will be shown. Schiro's four ideologies are summarised briefly as follows:

"*The Scholar academic ideology* assumes that the academic disciplines, the world of the intellect, and the world of knowledge are loosely equivalent. The central task of education is taken to be the extension of the components of this equivalence. Both on the cultural level, as reflected in the discovery of new truth, and on the individual level, as reflected in the enculturation of individuals into civilization's accumulated knowledge and ways of knowing"

The process that makes possible the establishment of knowledge is, in this ideology, what is understood by learning. For each school subject there must be a corresponding academic discipline. Because the disciplines are dynamic they are concerned as much with "what will be?" as with "what was?" The scholar academic ideology is teacher centred. Information is conveyed to the mind which reasons about it as required. Learning is the result of teaching. Because each discipline has within it, its own theory of learning, generalized theories of learning have no place in the design of instruction.

This ideology, in the view of many academics, is unfortunately linked to the social efficiency ideology.

The social efficiency ideology requires that the curriculum serves utilitarian purposes, namely the creation of wealth. Institutions have to be run like businesses: therefore, the curriculum has to be seen to be providing measurable outcomes in the form of objectives now called outcomes. In this paradigm the teacher's role is to guide (manage, direct and supervise) the learner to achieve the outcomes (or terminal performances) required. Knowledge is defined behaviourally in terms of what a student "will be able to do," as a result of learning. It is the prevailing curriculum ideology of policy makers. A criticism of the objectives approach is not intended, only its abuse. The social efficiency ideology has its origins in the objectives movement, and is in stark contrast to the learner-centred ideology.

The Learning Centred ideology is in stark contrast to the social efficiency ideology. The child is at the centre of, and has a profound influence on the curriculum process. This ideology is associated with the educational philosophy of John Dewey. It holds that the learning centred school should be totally different to the traditional school.

The Learner Centred curriculum is based on natural developmental growth rather than on demands external to it. "Individuals grow and learn intellectually, socially, emotionally and physically in their own unique and idiosyncratic ways and at their own individual rates rather than at a uniform manner"

The philosophy that underpins this ideology is constructivism. The schools and curriculum are designed to produce students who are "self-activated makers of meaning, as actively self-propelled agents of their own growth, and not as passive organisms to be filled or moulded by agents outside themselves". Learning moves from the concrete to the abstract.

The idea of active and passive learning has become part of the vocabulary of higher education, not in the sense of organizing an institution for active learning, but in the sense of teachers organizing and managing their classrooms for student centred active learning. The relationship between the teacher and the student is quite different to that established by educators from either the scholar academic or social efficiency ideologies, and Cowan argues, to be preferred [110].

Because knowledge is created by individuals as they interact with their environment, the objectives of a learner centred education are statements of the "experiences" the student should have. This view brings learner centred educators into conflict with those who believe that the objectives of an education are its measurable outcomes.

Learning Centred educators are opposed to the psychometric view of testing as expressed by social efficiency educators. Standardized tests are anathema to learner centred educators. It is assumed that students work is best assessed by students themselves hence the importance of learning logs and journals. Learning Centred tutors create communities of engagement, communities that care.

The social reconstruction ideology takes the view that society is doomed because its institutions are incapable of solving major social problems, therefore education should reconstruct society. Schools and their curriculum have to be designed to achieve this purpose. This is in marked contrast to universities where little thought is given to the design of buildings for learning. The models they have inherited, and with which they appear to be satisfied, is a legacy of the industrial revolution.

Philosophically this ideology has its foundations in John Dewey's *Reconstruction in Philosophy* and *Democracy and Education* [111; 112]. As might be expected it is founded on a social constructivist view of knowledge – knowledge is relative. The purpose of teaching is to stimulate students to reconstruct themselves so that they can help reconstruct society. Some authors who can be associated with this ideology see teaching as a subversive activity [113].

Heywood has argued that a higher education curriculum seeking to respond to current arguments for change will have components that derive from each of these ideologies [114]. Cheville arrives at much the same conclusion from a study of inequality in STEM education [115]. Following Muller [116] he distinguishes between two curriculum scenarios. The first relates to curricular that are focused on content; the second, to curricular focussed on action. Applying Barnett and Coate's curriculum modes (intentions of learning) [117] "knowing" belongs to scenario 1 and "acting" to scenario 2. In Schiro's ideologies scenario 1 is described by the scholar academic and social efficiency ideologies, and the learner centred and social reconstruction ideologies are described by scenario 2.

Barnett and Coate's third curriculum mode is "being". It is related to understanding of "who we are" on the one hand, and on the other hand to "what it is like to be". It links all the ideologies because we cannot "be" without knowledge, or without relationships to others.

The curriculum is an enabling process toward "being", that is, it is "developmental". That process is at the heart of what a university should be about according to Newman [118]. Therefore, these arguments do not just apply to STEM students but to all undergraduates. The curriculum should contain elements of both scenarios or of all four ideologies. Any definition of human capital has necessarily to embrace all three intentions of learning; attention to only one necessarily limits the potential of the individual. A utilitarian model focussing only on a social efficiency model is harmful of both the individual and society.

However, policy makers tend to believe in the scholar academic and social efficiency ideologies. These are consistent with utilitarian philosophy and the economist's model of the rational economic individual famously described by Douglas McGregor as "Theory X" in "*The Human Side of Enterprise*" [119]. Ideologies like this are deeply embedded on our thinking, and although irrational in the light research based educational thinking are nevertheless difficult to change unless they are profoundly disrupted. Fortunately, Schiro found among a small sample that most educators changed their ideology several times during their teaching career, and some held more than one ideology at the same time.

Currently academics, commonly economists and industrialists who advise governments state needs in general terms, and there seems to be considerable agreement among them about what these are. David Autor, for example, suggests that many of the new middle skill jobs will persist into the future and will combine routine tasks with tasks where workers have a comparative advantage because of the need for interpersonal interaction, flexibility, adaptability and problem solving [120].

It is within interpersonal activities that communication is important. Complaints that graduates lack communication skills have, as was indicated above, persisted for decades. Also related to interpersonal interaction are those qualities listed under the generic title of emotional and social intelligence. Similarly employers have argued that employees need to be flexible, adaptable and good problem solvers. It is surprising that problem solving keeps recurring since STEM subjects are supposed to develop problem solving skills which suggests that problem solving as taught addresses specific types of problem, and that the skill of transfer to the type of problem required to be solved in industry may be neglected. The terms adaptability and flexibility have been around for a long time. They come to prominence fairly regularly but they are completely ambiguous!

4.2 Adaptability

It is by no means clear what those who require persons to be adaptable mean by adaptability. Currently it often seems to means adaptation to a new technology that an organization wishes to introduce. This has been a problem with automation since its beginning and early studies of the impact of automation on the workforce and its adaptability spawned the concept of the socio-technical system and socio-technical systems theory [121]. While flexibility is clearly related to adaptability it can refer to those situations where individuals capable of doing other work are reluctant to do that work. The U.K. is sold to industrialists on the ground that its labour market is more flexible than those in other countries, as for example, compared with France.

But there is also the problem of the impact that a new technology has on society. For the most part individuals accept what is available. People have readily taken to devices that improve

family life e.g. washing machines, dish washers. They change their mobile (cell) phones with every up-date, and they accept much of what is forced them, as for example, changes in methods of banking. Authors such as Jaron Lanier have not persuaded us that the IT companies should pay for the information they have about us [122]. Swedes are now accepting hand implants of micro-chips that enable them to make financial transactions.

4.3 Adaptability and the transfer of learning

Of particular concern is the adaptation that individuals have to make when they transfer jobs. But what is adaptation? Looked at from the perspective change the factors that impede innovation in an organization, or prevent a society from adapting to a new circumstance, are the same factors that inhibit individuals from learning. From the perspective of change, individuals and organizations may be regarded as learners or learning systems. Neither individuals nor organizations can adapt if they cannot learn. Thus a key function of those who govern or manage is to create an environment conducive to learning. Since, according to Sternberg, intelligence is the ability to select and to shape the real world in which we live [123], we too, have a responsibility to help those whom we allow to lead and manage to create that environment [124].

If learning and decision making are held to be the same thing, that is, goal seeking behaviours, then the activity of learning is an adaptive response. That depends on what is commonly called the "transfer of learning", and that may not be accomplished without difficulty.

Academic subjects are structured so that beginning from a base the learner develops exosting skills and knowledge and acquires new skills in order to be able to deal with any problems they may face when they have completed their studies. The ability to solve unforeseen problems is called the transfer of learning. In this sense knowledge is subservient to skill or the servant of skill. At each level of the hierarchy of learning the student acquires new capacities for transfer. It is useful to think of this as a vertical transfer happening within the boundaries of the subject. But the subject is divided up into disciplines and students may find vertical transfer difficult. Within subject or vertical transfer cannot be taken for granted. It cannot be left to chance or osmosis. A study conducted by A. S Luchins showed that students solving mathematical problems used the same problem solving strategy irrespective of whether it was the most appropriate strategy, an effect that he called set-mechanization [125]. In an action research in the classroom with graduates training to be teachers it was found that transfer improved once the graduates had been shown examples of what was wanted [126].

Assessment has a key role to play in the development of within-subject transfer through question design. Given that transfer can only occur to the extent that students expect it to wide ranging questions should help the student understand the new situation. Transfer will not be possible if the person seeking to understand a new situation does not understand the concepts and principles involved. It is incumbent, therefore, on teachers to ensure their students understand the concepts and principles before they move their instruction forward [127]. Of equal importance is the fact that knowledge of models of problem solving and critical thinking will better enable students to handle new situations and develop reflective

practice or meta-cognition. To put in another way, students should benefit when they learn how to learn.

The transfer that is of more importance to the argument submitted here is horizontal transfer. This occurs when a student is asked to move out of within subject vertical learning to another subject that may or may not be cognate. In the case of mathematics and engineering that should be relatively easy but there are many examples of where the mathematics is judged correct but the physical explanation is incorrect [128]. As the cognate distance between subjects increases it seems that greater difficulty may be experienced with transfer. Brad Kallenberg calls this type of transfer cross-domain-transfer (CDT) [129]. It is useful to think of the cognate distance between two subjects i.e. subjects that have close cognate connections compared with subjects whose cognate connections are apparently distant although the cognate distance between subjects may not always be clear. Kallenberg has argued that practical reasoning can be assisted if the reasoner looks outside the box whether it is solving an issue in engineering ethics or engineering design. In particular he claims "that religious narratives can serve as one kind of source for CDT that lies outside of engineering proper. Complex problems are likely, more often than not, to contain cognate elements that are distant from the problem solvers cognate spectrum. The question is whether you see it?" . Hence, the need to learn to see things from a distance. Elsewhere Dias has demonstrated the close cognate relationship that exists between history and engineering [130].

The transfer that is of particular interest here is the transfer of skill that has to be made when a person changes jobs that are not closely related, and in particular to transfer from one mind set (way of thinking) to another [131]. Following the argument set out previously this may become increasingly necessary. A person may need some training, but if it is to be effective individuals in that situation will be helped if in their higher education they have been trained in learning-how-to-learn. It is not sufficient to leave them on their own to study and hope they become independent learners. Clearly they will be better prepared if they have had a broad education because they may have some familiarity, insight, into the job situation with which they are faced. In any case individuals will try and find employment that lies within the spectrum of knowledge that interests them which is a further argument in favour of a broad education. A university education should have as its primary goal the enlargement of mind, so John Henry Newman argued.

4.4 The responsibility of employers

If schemes like the one suggested are to work employers have to believe that employees are likely to have more skills available to them than is apparent from their job descriptor. This is the value of records of achievement or career portfolios [132]. In the past employers, particularly in Britain, have been reluctant to take persons even in engineering jobs when they do not perceive the person to have the specific skills they need. Coupled with the need to acquire a new work identity this can lead to a self-fulfilling hypothesis that employees'

come to believe they are only suitable for work in the areas for which they have been specifically trained as indicated by their job titles. Is this "*occupational transfer gap*" real or imagined? I suggest that it is imagined and that it is a perceptual problem. Most employees are likely to have skills that cross the divide of job perceptions for which reason we need to have a skills approach to defining jobs [133] that is accompanied by educational programmes that encourage the possession of wide ranging interests and knowledge.

Thomas and Madigan identified this problem when they studied what happened to workers made redundant from the aircraft industry [134]. They suggested that there is need for employees and employers to think in terms of *labour arenas*. Youngman, Oxtoby, Monk and Heywood when developing a new approach to task analysing engineers at work conceived of a labour arena as being a group of skills already possessed or which may be readily acquired [135]. It should enable the divide created by perceptions derived from job titles to be crossed to other less cognate jobs. They suggested that their technique of job analysis could be used to identify such arenas. In the model of higher 'permanent' education proposed the task of assessment is to identify the skills a person possesses, to identify weaknesses and remedy them, and to identify other skills that might be developed.

The model requires that employers who expect their employees to have to change jobs even to leaving the firm take responsibility for the development of personnel, and in particular motivating them to learn. They will help themselves and their employees if they regard their organization as a learning system. The concept of organizations as learning systems was popularised by P. M. Senge [136]. His model differs from that described by Youngman and his colleagues which shows the organization in problem solving and decision making modes (Figure 3). The learning curves are similar to Richard Foster's 'S' curves which describe the effort put into improving the product or process, and the results the company obtained from investment (See Figure 3 (i) [137]. It will be seen that this curve parallels the learning curves in Figure 3 (ii) and that each new adaptation (Figure 3(i-b; 3ll-d) represents an additional cost. In Foster's model a new-product process starts a new S curve (Figure 3(b)), and in this respect Foster's model adds an important dimension to the model. The curves in Figure 3(ii) show that from the acquisition of an idea the company goes through the same processes of learning as individuals except that the phases take place over a long period of time. Heywood has argued that the factors that enhance or impede learning impede or enhance innovation in the organization [138]. Such organizations are communities of learning (see section 4.7). That learning is enhanced if it is 'enlarged'.

Performance

(b)

(a)

Funding

(i)

(a) (not to scale) (b)

(c) (d)

(e)

(f)

(ii)
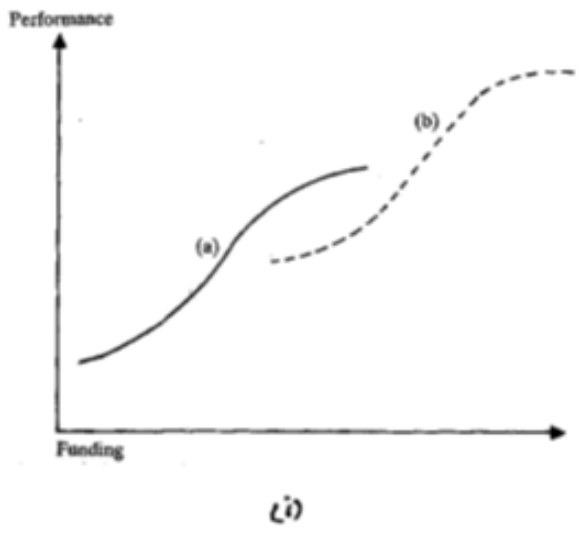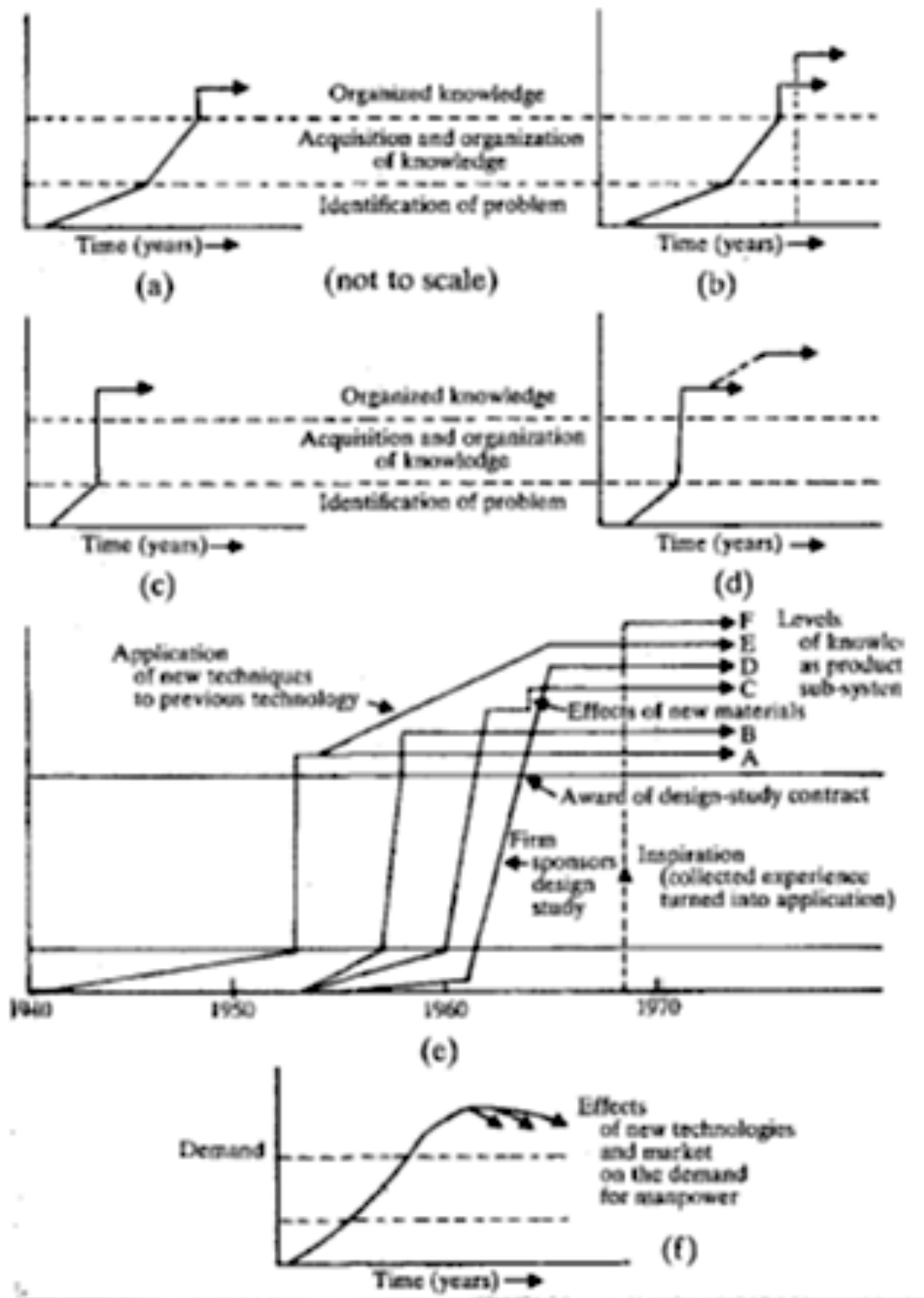
Figure 3

4.5 Enlargement of the mind and adaptability

The requirement that we should become more adaptable makes its own case for a broad education. However, it does not dictate what that breadth should be or how it should be structured. It does mean that however the curriculum is structured it should focus on what John Henry Newman called "enlargement or expansion of mind" [139]. For Newman enlargement like knowledge was a process through which a person obtained a philosophical disposition or wisdom. Therefore, one of the aims of higher education is to help students acquire the knowledge and skills necessary to enlarge their minds. Often when he is writing about what today are called the outcomes of university education Newman uses terms and phrases from which we can only conclude that he embraced all those domains of the person that are non- cognitional. For example "such an intellect […] cannot be impetuous, cannot be at a loss, cannot but be patient, collected, and majestically calm" [140]. It is to be found in his idea of a university tutor and the value placed on residence. For us, it is a reminder that the skills of the affective domain are as important as those in the cognitive domain which is the point that industrialists are making when they demand personal transferable skills.

Newman argued that "knowledge itself, though a condition of the mind's enlargement, yet whatever be its range, is not the very thing that enlarges it" [141]. Rather it is the ability to perceive the relationships between subjects. "Enlargement consists in the comparisons of the subjects of knowledge one with another. We feel ourselves to be ranging freely when we not only learn something but when we also refer it to what we know before [142]This would seem to be consistent with that present-day view of learning that it is the process by which experience develops new and reorganizes old responses [143]. This is clearly what happens or should happen within courses. Without it there could be no development or movement within a course. But demonstrating that knowledge has been acquired is no guarantee that there has been enlargement.

Adaptability arises from a person's ability to think and reason. It is these abilities applied across a range of subjects that enlarge the mind. The one thing in which we are all engaged is reasoning. We are all engaged in "deducing well or ill, conclusions from premises, each concerning the subject of his own particular business"- "The man who has learnt to think, and to reason and to compare, and to discriminate and analyse …will not at once be a lawyer […], or a physician, or a good landlord, or a man of business, or soldier, or engineer, or chemist […] but he will be placed in that state of intellect in which he can take up any one of the sciences, or callings I have referred to, or any other for which he has a taste or special talent […]" [144]. That is the essence of an educated person.

But in today's understanding "transfer" will not take place if these subjects are taught independently of each other [145]. Since transfer will only occur to the extent we expect it to occur, the curriculum has to show how it can occur in what might be best described as interdisciplinary or trans-disciplinary situations. The failure to approach study in this way is the reason why a general education that comprises the study of a number of independently organized subjects is not liberal. It is the reason why in subject specialisms like engineering so many students are unable to combine knowledge from the sub-disciplines to solve complex problems. Taught in a way that overcomes this problem, that is, in a spirit of

universality, engineering is as much a liberal study as any other [146]. Any detailed analysis of the activity (process) of engineering will demonstrate that this is so.

4.6 Expertise and liberal education

The results of the referendum in the U.K and the election for President in the United States shocked their respective establishments [147]. Immediately it was argued in the U.K .that the populists were illiterate. Graduates had been found to vote in large numbers for the losing side. Moreover, the losers found it difficult to understand why the views of large numbers of so-called experts had been rejected. Both of these views may be questioned. First, the assumption that because a person has a degree he/she has some general intellectual advantage over a person who has not. The most that can be said is that that person has an academic advantage. They may well have a higher intelligence quotient but that is not necessarily accompanied by practical intelligence or wisdom. Second, there are many examples of expert views being found wanting, and expertise was questioned by some politicians who in other circumstances would regard themselves as experts! [148]. Be that as it may, the greater problem is the notion put forward by politicians, apparently unconscious of the contradiction that political decision making should be left to experts.

That said there will be general agreement to the assertion that every person in a democracy should be able to engage in political debate irrespective of educational attainment. It is also likely to be agreed that the level of debate will be raised if they have had a high level of liberal education as defined by Newman, and that is the second, if not more important point in support of a liberal education, the object of which is to give the student a unified vision of reality. The point of a University is to make available the widest possible range of studies which while students will not be able to study all of them, "they will be the gainers by living among those and under those who represent the whole circle " (p 101, 149).

"This I conceive to be the advantage of a seat of universal learning, considered as a place of education. An assemblage of learned men, zealous for their own sciences, and rivals of each other, are brought, by familiar intercourse, and for the sake of intellectual peace, to adjust together the claims and relations of their respective subjects of investigation. They learn to respect, to consult to aid each other. Thus is created a pure and clear atmosphere of thought, which the student also breathes, though in his own case he only pursues a few sciences out of the multitude" [p101, 150].

It is the principle of the collegiate university. Thus "when a multitude of young men, keen and open hearted, sympathetic and observant, as young men are, come together and freely mix with each other, they are sure to learn from one another, even if there be no one to teach them […] A parallel teaching is necessary for our social being, and it is secured by a large school or a college; and this effect may be fairly called in its own department an enlargement of mind" [p 146, 151].

Fast forward 100 or so years and the UK Ministry of Education is found to suggest how technical colleges might introduce liberal studies in their colleges [152]. Those Colleges of Advanced Technology that wished to offer Diploma in Technology courses were required to include programmes of liberal study. The reason for not requiring technology students in universities to undertake programmes of liberal study, apart from the fact that universities

were regarded as private self-governing institutions, seems to have been that the student environment they provided was liberal, and the views cited above supported their case.

In 1977 Alexander Astin published a major study of the impact of liberal arts colleges on students in the United States. It was titled, "*Four Critical Years*". When he published a revised version in 1993 he added to the title "*What Matters in College*" [153]. While Newman is not referenced the results give considerable support to his views. Indeed Astin specifically supports the Oxbridge model. He writes, "This study has shown, once again, that this traditional model of undergraduate education leads to favourable educational results across a broad spectrum of cognitive and affective outcomes and in most areas of student satisfaction. Perhaps most important, however, is the finding that institutional structure, as such, is not a key ingredient; rather it is the kinds of peer groups and faculty environments that tend to emerge under these different structures" [p 413, 154]. The similarities with the findings of the Hamilton College study will be apparent. The problem is how to arrange the learning environment to achieve these goals. Related to this discussion is the question, "Can the circumstances of small group learning be repeated in distance learning?"

4.7 Conclusion: Community and learning

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 the 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 concept of "community" (the full expression of their togetherness by members of a society – in personal communion through culture) [155]. 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" [156], and I would add to ourselves. Some might consider that Universities have a major obligation to ensure they function as a community given that technology has substantially reduced shared experience and debate which is a major cost to society [157].

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" [158]. 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" [159].

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 the "person centred approach adopted by the Viennese researchers Renate Motschnig-Pitrik and Katherine Figl for the development of these skills among computer scientists [160].

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* [161], or the UK Employment Department's statement of learning outcomes in *Enterprise Learning and its Assessment* [162]*,* or more significantly Sternberg's list of abilities that contribute to intelligence in *A Triarchic View of Intelligence* [163] 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 relationships. 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. Nevertheless, reason seems to be withheld even on the face of evidence. One reason for this is the socio-cultural history of the curriculum of a particular country.

Part V

Problems with Pathways: Reconciling the Academic and Vocational

5.1 Status and social mobility

The idea of having a number of pathways that suit the aptitudes, attitudes and motivation of students would be sound if it was supported by prevailing culture. Unfortunately, education as an end in itself is seldom possible. As we have seen, at the present time it is utilitarian and used to train people for jobs. Many people in the working and middle classes hope these jobs will give them some social mobility. In this respect educational status is important and the pursuit of a university degree is tied to this goal.

In the U.K. in the 1950's the technical colleges provided a number of alternative pathways into careers, particularly in science and technology through alternative qualification paths leading to Higher National Certificates and the City and Guilds Insignia. The course had the advantage of combining work with daytime study (day release) of offered by an employer. It should be added that many industrial and commercial organizations cared rather more about whether you could do the job than whether you had a qualification, or should be supported on obtaining one.

In such circumstances no wonder individuals seek to obtain a degree irrespective of its renumeration value. To put it in another away it is better to delay the choice of specialism as long as possible. If students are aware of who makes it in society, that is those who go to Oxbridge and obtain degrees in the classics and PPE [165], then they are less likely to choose to qualify as technologists

All this is reinforced by a school system in which the academic is regarded as superior to the vocational or practical support for which can be traced back to Aristotle. In the middle of the last century following the U.K 1944 Education Act schools were divided into three categories. Grammar, Technical and Modern. Students were selected into these schools at 11 years by means of an aptitude test commonly known as an IQ test. So from the age of eleven some students were made to think they were more intelligent than others and others that they were less intelligent. There were never enough technical schools so only a small part of the population remained at school after the school leaving age of 15 in order to take the university entrance examinations known as the Advanced levels of the General Certificate of Education (see appendix-note 5). The majority of population left school at 15+ but they had available the technical college/further education route by part-time study. There was never any evidence to support the claim that if you were not academically able you would do better at practical subjects. Indeed Macfarlane Smith's work on spatial ability suggested that grammar school students were disadvantaged by not doing subjects like technical drawing, woodwork, and metalwork [165].

Although the school system was changed in the late 1960's and 1970's to a non-selective comprehensive system the ministry of Education failed to complete the task and some local education authorities retain grammar schools, just over 160 in number. Many members of the conservative party wish to increase the number of grammar schools and it is currently that party's policy. However, if you wish to be sure of a place at Oxbridge your chances are much

higher if you go to one of the fee paying private schools which belong to the Headmasters Conference. If you cannot afford the fees which the majority of professional people cannot then the next best thing is a grammar school.

The Grammar schools offer an academic curriculum in which subjects like mathematics have more status than, say geography. Craft subjects have very low status and may not be offered. A substantial attempt by the Joint Matriculation Board to introduce Engineering Science as an equivalent to Physics at the Advanced level was wound up after about twenty years because it could not obtain a sufficient number of students to make it economically viable. Woodwork and metal work developed into Craft, Design and Technology (CDT). Attempts to give this subject status by Sir Keith Joseph a Minister for Education failed.

It is in this light that the recommendations of commentators reported above that more students should be persuaded away from the university route to the vocational route should be seen. It is by no means clear that if independent schools persuade some of their students to undertake apprenticeships that this will change the status of vocational education [166]. Indeed without severe disruption it is unlikely to happen. If authorities like Steven Hawking and Max Tegmark are to be believed then developments in AI have that power [167]. But for a disruption to cause change ideas that can be taken up have to be prevalent in the system. They also have to be plausible. In the next section the role of engineering and technology in a stage of "romance" is considered.

5.2 The role of engineering and technology in a stage of "romance".

Following Krupczak and his colleagues [168] engineering is taken to be a process that produces and artefact (or idea). That product is commonly called a technology. Taken together they are the art and science of making things that meet the needs of self and society. It is an activity and central to that activity is "design." It is an activity that is a service to both individuals and society that continually creates new problems for both. It is used to create change and at the same time creates the need for change. It requires individuals to develop the skill of adaptability which includes the ability to judge the merits or otherwise of a particular innovation.

 They are modelled in figure 4 which conflates the two literacies. Clearly, the products of engineering and the technologies interact at all levels of society. This can be seen from the influence of electro-mechanical devices in the kitchen and the impact they have had on families, or at a societal level, as for example, in the concern that communities have for processes like *fracking* which enable large quantities of gas to be extracted from shale. At the micro-level changes in kitchen technology or for that matter electronics in the home are adapted to without much thought. Not so when a community is faced with *fracking*. While cell (mobile) phones were quickly accepted some communities reacted unfavourably to the systems antennas because of fears of cancer. To persuade communities of the value of a technology the promoters will offer engineering explanations for the acceptance of the technology which the community will be expected to take on trust. For communities to make a rational decision they will have to have some knowledge of risk and some understanding of the engineering together with an ability to synthesize the two. In a word, they will need to be engineering and technologically literate.

Figure 4. Model of the way in which engineering and technology support society and the economy [169].
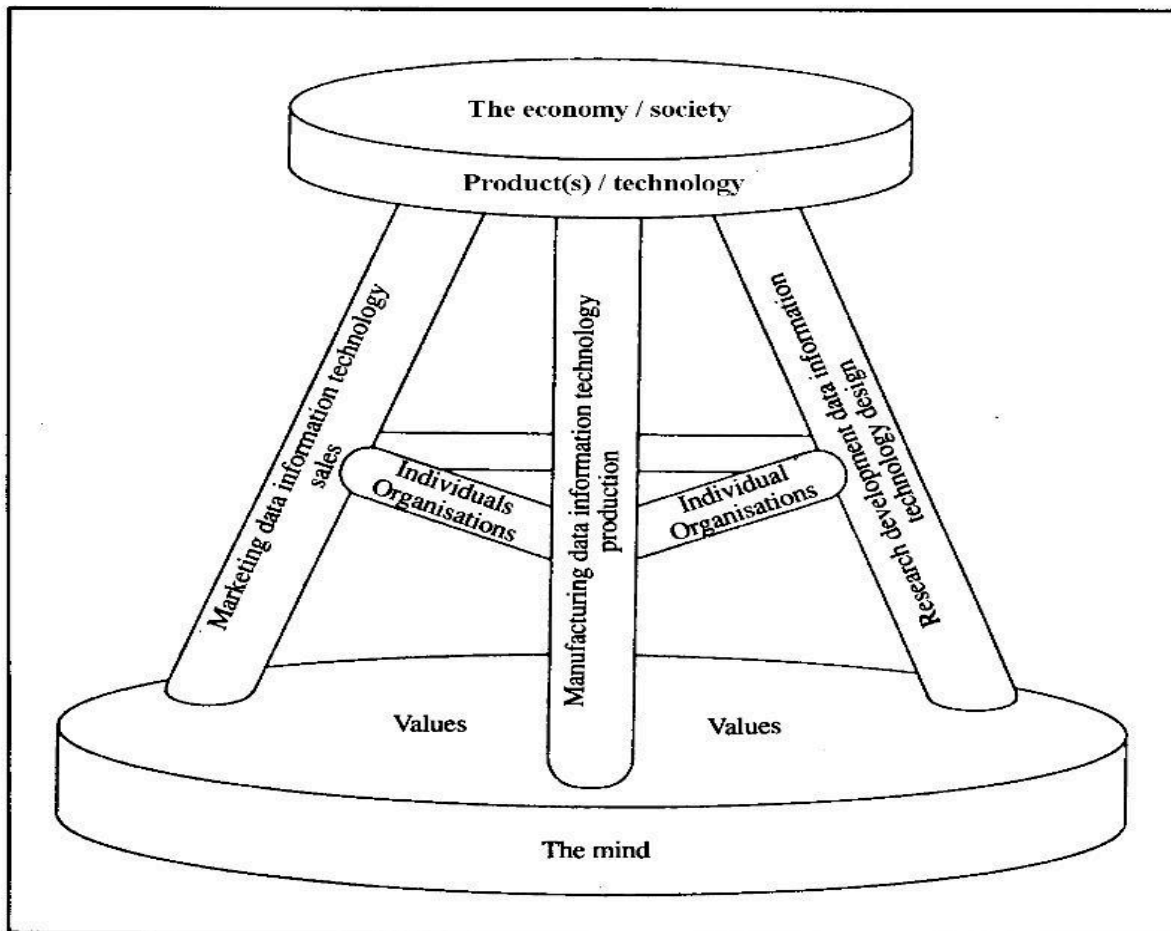
But technology has other, perhaps more insidious effects in the home. For example children are able to use the internet to view pornography. For some parents there is evidently no moral issue about viewing pornography, but for the majority there is. While there is no need for a detailed understanding of technology to resolve this issue there is clearly a need to understand our value system as well as those of others. So any program in technological literacy has to function at different levels of apprehension, and with different dimensions of knowledge ranging from the technological to the philosophical and theological.

The base of the model on figure 4 represents the person. The mind which supports the whole activity is the source of our values, beliefs and technical understanding: it is the source of the attitudes and opinions that we bring to the different social systems we have to occupy; it is the driver of our actions. Understanding how our beliefs and values (moral and otherwise) are formed is important for our conduct as engineers and individuals. It is at the core of any programme of liberal education. It governs how we adapt to the plurality of social systems in which we live.

There is, however, another dimension of technological literacy that relates to engineering in quite a different way. Inspection of figure 4 shows that the engineering processes that take place in the legs of the stool have to be bound together by organizational structure. It

inevitably involves people (as individuals) in some function or another. Thus, the process of engineering is carried out by technological systems of two kinds: (1) the systems that manufacture, and (2) the systems that cause and control the manufacture. Both are social and technical in the same way that technology is part of a more general social-technical system. Following Krupczak et al engineering is the process of realising a design in a technology which is used in society. It is for this reason that this model of engineering and technology necessarily conflates the two literacies, while at the same time (1) showing the different educational needs that have to be satisfied, and (2) demonstrating that it contributes to a programme of liberal education.

Engineering and technological literacy have as their objectives, the appreciation of engineering and technology through an understanding of the relationships as represented by the model.

 A major aim should be to address that major misunderstanding of western society which assumes that technology has a "*life of its own*", and gives over control to that life [170]. It is as Bucciarelli says that it is "romantic nonsense to think and talk this way out here in the big world. So too to imagine we can perfect a missile defense shield, that we can profit from the genetic manipulation of life at all levels without occasioning significant collateral damage, or that we can convince every scientist that global warming is upon us before it is too late to do anything about it- all of this is wishful thinking. It follows from a seriously flawed vision of technology, one that sets it apart and aloof, distant and seemingly out of reach of ordinary people. As citizens we ought to know and do better" [171]. It also follows that a person who has not an acquaintance with engineering is not a liberally educated person. Nevertheless, from the perspective of liberal education the model is incomplete. For example, there is no requirement for history, the fine arts and music, literature or the learning of a language other than one's own, although it assumes that it would include "making" things. Practical skills not only contribute to the development of spatial ability and creativity but to the development of and understanding of tacit knowledge [172]. It is generally agreed that a liberal education would not be complete without attention to these. Fortunately, it is easy to insert them in the model. It is argued that the form of this curriculum should be basic to higher education.

5.3 Learning, teaching and the curriculum

This model of the curriculum provides for a reconciliation between academic and vocational education. Engineering and technological studies clearly contribute to a liberal education. Basic higher education should be likened to a spring board for specialist study while at the same time providing the key skill of transfer. But that depends on the "combination" of learning across subjects. A general education that consists of subjects taught separately without reference to each other is not a liberal education. Similarly an education that does not overtly pay attention to the skill of learning (learning-how-to-learn) is not liberal. The "combination" gives equal importance, to the person, society and the economy.

Just as Newman's epistemology justifies the curriculum model presented so there is an epistemology that indicates the most appropriate approach to the teaching and learning that integrated or trans-disciplinary studies require. It comes from the work of the Scottish philosopher John Macmurray.

He argued that "there is a necessary interplay, in all human activities, between theory and practice. It is characteristic of Man that he solves his practical problems by taking thought; and all his theoretical activities have their origins, at least, in his practical requirements. That they also find their meaning and significance in the practical field will command less general assent; yet it is, in my belief, the truth of the matter, and one of the major theses to be maintained here. Activities of ours which are purely theoretical, if this means that they have no reference to our practical life, must be purely imaginary-exercises of phantasy which are not even illusory unless we relate them to the practical world by a misplaced belief. The truth or falsity of the theoretical is to be found solely in its reference to the practical" [173].

Macmurray substituted "I do" for "I think" in Descarte's dictum *cogito ergo sum* As Macmurray put it in one of his lectures *cogito non ergo sum* [174]. All our activities begin with the practical. Finding out how to do what we want to do leads to our theories. We are our own agents [175]. So it is with learning, we learn that which we do. Therefore, the first stage of this curriculum should necessarily be problem or project based in which the problems or projects are arranged to ensure that the need for the other dimensions of knowledge and behaviour become apparent, and worthy of exploration. In this way skill in non-cognate transfer should be developed.

The mathematician philosopher Alfred North Whitehead provides a theory of how this stage of education should be regarded.

5.4 Whitehead's theory of rhythm in education [176]

The stages of Whitehead's theory of rhythm in education are summarised in exhibit 7. The first stage of romance is necessarily one of transdisciplinarity because it is a stage of exploration, a stage of discovery. So too is the final stage of generalization (synthesis). The curriculum described above is a stage of romance at the beginning of higher education. If as some argue the school curriculum needs to be extended then it would be a stage of generalization.

Between romance and generalization there is a stage of precision. It is here that the language, which is the "style" of a particular subject, is learnt; and the interest found in the stage of romance turned into a search for expertise. Secondary schooling and higher education emphasis focus on precision. But, Whitehead does not expect the stage of romance to be one that is simply a collection of "scraps of information". In his lecture on the aims of education to mathematics teachers he said, "Culture is activity of thought, and receptiveness to beauty and humane feeling. Scraps of information have nothing to do with it. A merely well informed man is the most useless bore on God's earth. What we should aim at producing are [is] persons [men] who possess both culture and expert knowledge in some special direction. Their expert knowledge will give them ground to start from, and their culture will lead them as deep as philosophy and as high as art" [177, p 1]. Education is then, "the acquisition of the art of utilisation of knowledge" [178, p 6]. The stage of "romance" is not only one of discovery but of creative exploration [179]. It is a view that fits well with what an engineer seeks to do.

Stage 1: Romance: The stage of first apprehension (a stage of ferment). Education must essentially be a setting in order of a ferment already stirring in the mind: you cannot educate the mind *in vacuo*. In our conception of education we tend to confine it to the second stage of the cycle, namely precision [ ] In this stage

knowledge is not dominated by systematic procedure [ ] Romantic emotion is essentially the excitement consequent on the transition from bare facts to first realisations of the import of their unexplored relationships.
Stage 2: Precision:
The stage of romance-width of relationship is subordinated to exactness of formulation. It is the stage of grammar, the grammar of language and the grammar of science. It proceeds by forcing on the students' acceptance a given way of analysing the facts, bit by bit. New facts are added but they are the facts which fit into the analysis.
Stage 3: Generalisation:
Hegel's stage of synthesis. A return to romanticism with the added advantage of classified ideas and relevant technique.

Exhibit 7. Whitehead's theory of rhythm in the educational process. The stages of mental growth and the nature of education. A summary of pp 27 – 30 of the essay on The Rhythm of Education.

5.5 The goals of a stage of "romance" in a program for engineering and technological literacy

Beyond learning the skill of transfer the stage of romance should achieve five other goals, the first of which is motivation. Motivation is seldom spelt out as an aim of education yet it is not an un-trivial aim especially where unusual courses, that is, those that step outside the plausibility of the perceivers, are concerned [180]. Currently programs of engineering and technological literacy (long or short) seem to fit this category. For them to be successful they have to send a message back to the student body that they are interesting, entertaining and worth learning. The key questions for the tutor and curriculum designer are "how do I motivate students through my teaching?" (i.e., "what instructional strategies are most likely to motivate the students?"); "what do I know about the students that will help me motivate them"? And, "am I likely to motivate them with curriculum structures as they are presently organised?" (By structure is meant the linear organization of the timetable into subjects). Motivation, instruction and learning are intimately linked.

The second goal is the exploration of different ways of knowing and learning. It is not at all obvious that entering students will see that it is necessary for them to bridge the gap between the "liberal" and the "vocational." They will have been schooled in educational systems that are classified by subjects and where the distinctions between them are emphasised and therefore, between liberal and professional (vocational) knowledge rather than the seamless pattern to which they belong. For this reason students should be invited to explore different ways of conceiving knowledge including their own, and how it may be re- structured in order that they may use it in specialist study. Related to this is the need to understand how we learn, and how we develop the reflective capacity that is indicative of higher order thinking. One of the major advantages of incorporating the fine arts into liberal education is that it forces on the learner an appreciation that there are many ways of thinking about objects in the real world such as connoisseurship [181].

Apart from the value of understanding how our learning styles influence the way we learn and our responses to different kinds of instruction our perceptions also influence our learning. Perception is an over-arching concept that plays an important part in the way we relate to each other in the workplace, social settings, and the classrooms [1782, Ch 2]. As Bucciarelli has pointed out very often the problems teachers have in seeing the way their students understand a particular problem is because they have not learnt to speak the same language

[183, p 92]. Engineers who are used as expert witnesses have to learn how lawyers use evidence, and what their role is in giving evidence [184, p 46]. Each of the dimensions of engineering and technology is a different "style" or way of thinking - a different "language".

In science and engineering there have been many studies that show students often have misconceptions of the principles that are to be understood. They have led to different epistemologies such as constructivism in attempts to show why this happens and how the problem can be averted through different approaches to instruction [185, p 57 ff).

The third goal is the exploration of one's personal value system. The base of all engineering and technological activity is the value system that we hold. Our beliefs and attitudes drive our personal and working behaviours. The person who is engineering and technologically literate should be grounded in a well thought out ethic. One way of arriving at an ethical position might be to examine the constructivist/realist philosophies in their response to the fundamental issues of ethics [186]. Another way might be to examine theories of moral development such as Kohlberg's [187] and how they might inform self-development the fourth goal of the stage of "romance" on the one hand, and to the concept of moral autonomy in engineering on the other hand [18].

The fourth goal is to provide for personal development. Whitehead's stage theory is clearly related to his view that "the valuable intellectual development is self-development [189, p1]. The teaching strategies we choose can enhance or impede development. Most education systems and teaching emphasise cognitive development at the expense of the affective even though it is well understood that in life individuals are expected to work in teams and that the effectiveness with which teams function is dependent on the emotional intelligences of their participants. The argument here is, however, that it (development) goes on throughout the whole of life, and that each transition, primarily a change in work and/or personal (family) circumstances is a stage that is accompanied by new insights and as such is a stage in development. The idea that intellectual development is self-development commands some assent but it needs to be unravelled further.

Clearly there are two quite different dimensions at issue. There is personal development and there is development in engineering and technological literacy. Are they separate or do they live together? In either case the peak of development is the reflective capacity with which it endows an individual. As Macmurray points out this must embrace the intellectual and the emotional: both are activities of knowing [190, p 196 ff]. A criticism of engineering education, and indeed other subjects within higher education is that they concentrate on the intellectual at the expense of the emotional although within recent years there has been recognition by industry that it needs individuals who have a balanced emotional intelligence, that is, it has assigned significance to the affective dimension of human behaviour. Students might be asked to discuss the question, "Given that our actions so often hurt the feelings of others should our understanding of "reason" embrace feeling and action?" Asking this or similar questions invites the students (us) to consider whether thinking and acting, emotion and reason, and freedom and responsibility are opposites? [191, p 17].

The fifth goal is to provide practical experience of designing and making things. Much of life is an inherently practical activity. It embraces design, investigation and the making of things. They add skills without which any program of liberal education is incomplete. If the views of such authorities as Tegmark [192] and his colleagues prevail, and we have much more leisure, then the true value of subjects like Home Economics, Art, Music and Craft, Design and Technology will come to be seen.

It is clear that a stage of romance that is directed toward the attainment of these goals will necessarily draw students through the cycles requiring some precision and some generalisation appropriate to the student's knowledge at the time as they search understanding. In Bruner's terms it is the first stage of the spiral in a student's personal curriculum [193]. It follows that the provision for learning in a stage of romance has to include activities that will help develop a student's reflective capacity both with respect to himself or herself as a person or a person engaged in work activities of any kind. And, that is the foundation for bridging the gap between the "liberal" and the "vocational".

This is to run against the trend in some countries of placing students in vocational studies earlier, or redirecting some potential university applicants from degree programmes that do not produce an adequate earnings return to vocational courses in institutions other than a university.

The programme described here reconciles the vocational with the practical. The contention here, which is supported by research, is that it is better to lengthen the period of general education within the context of the epistemology of liberal education as proposed by Newman. The research of Eric Hanushek and his colleagues lends support to this view as does the sociological analysis of the semi-professions by T. H. Marshall [194]. Hanushek writes that "policy proposals promoting vocational education focus on the school-to-work transition. But with technological change, gains in youth employment may be offset by less adaptability and diminished employment later in life." [195]. Hanushek and his colleagues found strong robust support for such a trade-off among 11 countries, more especially in those that emphasized apprenticeship programs for that age group. These included Germany whose dual system of education and training many in the U.K. would like to model.

The U.K. has always provided an excellent academic education for high achievers but it has always failed with the 50% who are not "supposedly" of university calibre as measured by crude measures of academic performance. This is problematic for the model of higher education promoted here because those students have not been found to be responsive to the general education provided and because of the national curriculum it is difficult if not impossible to consider alternatives. Given that automation and AI are having their biggest impact on the low level jobs that many of these students would normally have done this is a major problem and likely to be increasingly so in the future. As Baroness Wolf has pointed out the neglect of technical and further education where alternative curricula might be developed is extremely serious [196], this to a large extent being due to British snobbishness, to quote Lord Baker [197].

Burton R. Clark, an American sociologist explained the problem thus, "A major problem of democratic society is inconsistency between encouragement and the realities of limited

opportunity. Democracy asks individuals to act as if social mobility were universally possible: status is to be one by individual effort, and rewards are to accrue to those who try. But democratic societies also need selective training institutions, and hierarchical work organizations permit increasing fewer persons to succeed at ascending levels. Situations of opportunity are also situations of denial and failure" [198].

This was written in 1956. Substitute "automation and AI" for "hierarchical organizations" and it just about describes the position today and extends too many of those getting degrees today. So we come full circle to the question asked in section 1.1(a), "What is higher education for?" Clearly it goes beyond the economic for as Burton Clark wrote, "democratic societies need not only to motivate achievement but also to mollify those denied it in order to sustain motivation in the face of disappointment and to defect resentment" [199].

Clark called this the "cooling-out" function of education. Irrespective of level it has to be about seeking ways to help individuals to self-fulfilment which is much more than work. In this report it is argued that university (higher) education will better advance this goal if it is reorganized at the beginning by the inclusion of a stage of romance, and at its end to provide a base for learning throughout life.

5.6 The problem of "precision" and the costs of higher education

Currently the language of Whitehead's stage of "precision" is the primary goal of university courses and much of the three or four years spent in college is on courses in which it is emphasised. If the predictions discussed in earlier parts of study are in any way correct, the way and what of knowledge reception and skill will change radically. In the two year programme envisaged in the model presented, year 1 would be a stage of romance, and year two a stage preparatory precision. The two year Community Colleges in the U.S. are ideally suited to this model. The associate degree is an ideal qualification that can be used for closure for some students while others who would be free to continue their studies in other colleges, perhaps via specially designed bridging courses. For example, some colleges provide feeder courses to university courses of engineering [200], and this has happened in the U.K [201]. Equally the student could go into work and achieve degree level qualifications by other means.

It is interesting to note that in his 1983 commentary on the U.K. 1963 report of the Robbins Committee on Higher Education Sir Charles Carter wrote that an "obvious issue to be faced, if one is thinking about higher education as a whole, is the creation of community colleges which would offer opportunities more limited than a degree, but more widely available" [202]. The title has the quite positive advantage of not mentioning vocational, technical, or further.

In the model of "romance" presented above the focus subject is engineering and technology. The transdisciplinary element of the course introduces the student to philosophy, psychology and theology on one side of the spectrum and on the other side organizational psychology [203], finance, economics and sociology. But other subjects are studied as well.

Transdisciplinarity can be derived from problem studies on any subject on which the focus is placed [204].

In this model the life experiences of individuals take them through all the stages of the model. Both the stages of "romance" and "generalization" are stages when persons have their greatest potential to be creativity. The formal periods of learning are stages of precision that should also accomplish in individuals "renewal".

The view taken here is that the state should be responsible for the costs of basic higher education. In this model it would be for the first two years. It assumes that sufficient savings are made from shortening the course.

5.7. Summary and Conclusion

Educational change involving the curriculum even when evidenced base is extremely difficult to bring about unless it is politically and/or economically motivated. Often politicians drive change in the absence of evidence, or even an adequate philosophical rationale.

This study arose from questions about the impact of technology on the engineering workforce on the one hand [205], and on the other hand the development of a philosophical case for engineering and technological literacy as a component of liberal education [206].

The first study showed that the career patterns of engineers were changing. Many engineers would have to make several job changes each of which would require new knowledge some of which would be distantly cognate. It was inevitable that they would require some kind of education and training to prepare them for the professional and personal adjustments that would have to be made. It was also apparent that rather than occasional professional development courses education needs to be considered as a life process –"permanent" as it has sometimes been called, and that this had implications for the structure of educational systems and its financing.

It was also clear that technology and AI were impacting on the professions and that they would have to respond with changes in their requirements for membership. This writer suggested that a basic higher education of about two years full-time study should be provided after which the student would work in industry for a few years before taking a higher qualification [207]. It was likely that additional educational inputs would be required throughout life.

In the same paper it was reported that Alan Cheville "had taken this somewhat further. He suggests that students should take out an insurance policy for a life-long engagement with their university so that they can return to their university 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 would be profound". They would no longer signify an end of education but should be indicators of personal and professional progress, and assessment should indicate the labour arenas covered by the skills a person possesses.

Financially it represents a change from a mortgage based system of student finance with heavy borrowings re-payed over a life time to an insurance based system in which the regular investment sums are much smaller.

During the period of these studies it became clear that higher education was in a state of financial crisis. In the U.K John Denham had also proposed that the period of higher education should be shortened in order to save students money. In contrast to Heywood's two year model which may be applied to higher education generally, he proposed that three years of study should be compressed into two.

Given 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. This will require a rethinking of the concept of the "firm" and its role in society.

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 much 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.

Taking all these issues into account a model of liberal education applicable to all "permanent" (continuing) higher education based on the educational philosophies of Newman, Macmurray and Whitehead was presented that serves as a preparation for all three realities, the person, the job, and society.

APPENDIX

Trying to change a Sub-System of Higher Education

Introduction

Throughout the last century the system of higher education slowly but continuously changed. Small steps were taken and continuity maintained with the immediate past.

If anything, school systems in the western industrialised world are antipathetic to change. "The goals and functions of schooling working in concert with school and curriculum structures are potent influences in maintaining curricular continuity"[1]. Dewey's democratic schools did not become the norm for schooling. The same is true of higher education which provides its own exemplars from which lessons can be learnt. The one attempt at radical change in England and Wales failed. It is rarely referenced or discussed although there are lessons from that experience that continue to have relevance.

2. The 'failure' of the alternative system of higher technological education in England and Wales 1955 to 1966

Since the end World War II politicians in the U.K, the U.S and other industrialised nations have over seen the expansion higher education in the belief that it is necessary to have large numbers of graduates to secure the economic security of the particular nation concerned. In the U.K immediately following the second-world war a Committee of the Ministry of Education (The Percy Committee) was established to systematically plan the future of technical education, and to indicate the contributions that the universities and technical colleges should make to its development [2]. It reported in 1945. The philosophy propounded by the Committee continues to influence educational thinking even though that may not be widely understood.

In the U.K, higher technological education in 1945 could be conceived of as two competing sub-systems, both producing degree, or degree equivalent graduates. In contrast to the United States professional qualifications in education and technology could be obtained by students in technical colleges either by external degrees offered by some universities, or by a route designed specifically for students who were released by their employers for one day per week over a period of between 5 and 7 years: at the end of which they obtained by examination a certificate regarded as equivalent to a university degree Numerically they were as important as each other as exhibit A1 shows. However, they differed in terms of status, the university having higher status (both educational and social) than the technical college sub-system. Put crudely the universities catered for the middle and upper classes, and the technical colleges the working and lower middle classes. The ability of the technical colleges to offer degree or degree equivalent qualifications made them important agents of social mobility.

University sub-system	Technical College sub-system
Full or partial exemption from Professional Institution examinations by means of first degree	Full or partial exemption from Professional Institution examinations by means of Higher National Certificates
1900 (700)	2057 (1092)

Exhibit A1. Source G. L. Payne [3, p 215]. In terms of industrial need these figures will be understated because industry would employ graduates from other science positions and non-members of the institutions in engineering jobs. They also neglect those awarded internal and external degrees of the University of London by certain technical colleges. The figures in brackets are for degrees and Higher National Certificates only in 1939 reported by the Percy Committee.

The problem as the committee saw it was to maintain the output that had been achieved in the war, and that to achieve this goal there would have to be "an energetic expansion" in both sectors. They thought that 45% of the required output to meet industrial requirements should be met by the universities and 55% by the technical colleges. They propounded the philosophy that, "every technology is both a science and an art. In its aspect as a science it is concerned with general principles which are valid for every application; in its aspect as an art it is concerned with the special application of general principles to particular problems of production and utilisation." They concluded that because the "art" aspects were necessarily learnt in formal works training and the "science" aspects in academic study, technical colleges had in the past selected for and emphasised the "art" aspect. This led them to the view that that the different styles of training in the universities and technical colleges would lead to engineers with different qualities. It also led them to argue that the technical colleges should award a diploma rather than a degree although it was equivalent to a degree! At the risk of oversimplification the universities would train for research and the technical colleges for industry.

Universities would continue to offer courses in engineering science as relevant to the major fields (civil, electrical and mechanical), and certain technical colleges would be upgraded to offer continuous full time study of duration equivalent to a university course but interspersed with periods of industrial training. In the period following the report the idea of the "sandwich course" emerged. It was modelled on 4 six month periods of college study interspersed with 4 six month periods in industry, often described as a "thin" sandwich course.

In the event, and after much debate, in 1955, an organization was created that would regulate the award of diplomas in colleges (National Council for Technological Awards-NCTA). In the following year (1956) eight (subsequently nine) Colleges of Advanced Technology (CATs as they were known) were created for the purposes set down by the Percy Committee. [4]. Following recommendations of the Robbins Committee on higher education in 1963 the Colleges were given university status in 1966. In terms of the original goals set down by the Percy Committee the sub-system had failed. Why?

Figure A1 shows the sub-system from the perspective of the factors that influence student motivation as the student moves through the system. The sub-system expected to draw students from the grammar schools with entry qualifications the same as those that would be expected for university ('A' level [5]). Not shown in the model is the intake from industry

with ordinary national certificate qualifications [6]. The majority of students entered with 'A' levels in mathematics and science subjects.

The model underestimates the importance of the jobs that were available to graduates from the dip.tech route. Because they were in competition with university graduates they were dependent on industry and what industry perceived it wanted from this kind of graduate. Would they be able to get jobs in research or management, or were they required for more practical work? Similarly, the sub-system was also dependent on the support it got from industry in terms of training places.

As seen by the head teacher and teachers the purpose of the sixth forms was to get students into universities. They regarded the CATs as little more than technical colleges [7]. Given that about 50% of the students took notice of what their schools had to say it is not surprising that CAT's could not command the grade performance that universities could. Given that engineering was already undervalued by schools, and in consequence their brightest students were directed toward the universities, the CAT's were not in a very good position to obtain students with the best grades [8].

At the same time for those seeking financial aid throughout their higher education the dip. tech sandwich courses where the students were employees of the sponsoring firms (industry based) were attractive. College based studentships were not so attractive because the students had to find their own places. The larger proportion of students were industry based. Of all the possibilities open to industry for sponsorship the industry based dip.tech was the most expensive.

Clearly "status" had some influence on the failure of the system but so too may have "uniqueness" which is closely linked to status. The nine colleges chosen to be CAT's were not required to offer dip.tech courses. Almost all of the full time students at one of them in London pursued degrees of the University of London. The other two in London offered degrees alongside the dip.tech. On top of this competition some colleges that had not been made CATs were also allowed to offer dip.tech courses just as they had been able to offer and continue to offer degree programmes. That said, it is a moot point as to whether the system would have developed into a real alternative qualification for industry if the dip.tech had been confined to the 9 colleges and been their only qualification for the reason of "curriculum drift".

"Curriculum drift" is the process of mirroring the curriculum of higher status institutions. The reasons for this "curriculum drift" are not hard to find. They lie deeply in the social class structure of the U.K and the social status with which it is associated. Again, at the risk of oversimplification, engineering = trade = technical college = skilled working class, whereas science = profession = university= middle class. Academics in the CATs developed courses that mirrored those in the universities.

In this light it should come as no surprise that the government of the day accepted that attendance at a university as opposed to a technical college produced a liberally educated person. In 1957 as a consequence of a desire to broaden technical education the Ministry of Education had issued a circular that indicated how technical studies might be broadened [9]. It recommended that 15 to 20% of a student's time should be devoted to liberal studies. The NCTA continued with this requirement except that it should be about 10% of a student's time

[10]. There was a major debate about the extent to which the subjects offered should be "tool/fringe" or "cultural", a distinction that has current relevance [11].

Into this mix add the establishment in 1961 of the Robbins Committee to advise the government on the future of higher education which is not shown in the diagram but was nevertheless of considerable influence. This excited staff who already believed that since their courses were of degree standard they should be allowed to award degrees and not diplomas [12; 13]. The Robbins Committee accepted this view [14], and in 1966 the CATs obtained recognition as universities, and with that they began to offer traditional courses. It is in that respect that they must be considered to have failed. But, in terms of the vast majority of their teachers they were a success.

In crude terms the teachers also saw-off industrial criticisms of dip.tech courses in particular the "end-on" problem. Industrial Training Officers argued that it should be possible for the colleges to take in two intakes each year. This would mean that the colleges would have to be open for the whole year if this so-called "end-on" arrangement were to be introduced [15]. Some Principals believed that the number of students would increase considerably if their colleges adopted this structure but they were not particularly successful in promoting this idea although a few courses did adopt this arrangement [16]. One investigator found no evidence to support the belief that the number of students would double if the College adopted the end-on arrangement. Industry wanted the end-on arrangement so that it could have its training places filled throughout the year, which did not mean an increase in the number of training places [17]. An increase in the number of dip.tech students would have required an increase in the number of firms supporting the scheme. The investigator came to the conclusion that it was difficult to believe that firms supporting these courses were short of qualified manpower, a result which caused a stir at the 1963 annual meeting of the British Association for Commercial and Industrial Education [18]. Had there been a shortage of manpower the story might have been different. This is not the same as saying that there were not shortages in specific areas. Some industrialists reported that the more senior the post the more difficult it was to find suitable candidates!

The industrialists were sufficiently influential to persuade the National Advisory Council for Industry and Commerce to establish a committee on the problem [19]. Traditionally industry had not interfered in the curriculum offered by the colleges. However, certain industrialists, particularly in the electrical engineering industry as indicated above were dissatisfied with the direction that the dip.tech curriculum took. One of their number G. S. Bosworth the Director of Personnel and Training of the English Electric Co voiced his concerns publicly and in a paper in *Universities Quarterly* in 1963 [20]. The question arises as to whether it would have been possible to have introduced a radically different curriculum. Elsewhere, I have suggested that knowledge of what might have led to changes in approach, did not exist except in very broad terms [21]. Irrespective of a knowledge of learning theory as it was understood, it was appreciated that project based learning was of particular value hence the requirement that students complete a substantial project. But universities were also cottoning on to this idea [22], thus reducing the differences between the dip.tech and the university degree.

Much was made of the value of the possibility of "integration" between academic study and industrial training. It is difficult to determine what the participants thought "integration" might mean. From the student perspective what mattered was whether or not the experience

given was good or bad, and this was the approach taken to the evaluation of industrial training by investigators [23]. No theory was advanced that could have been tested. In this writer's view, it is only in the last decade or so with investigations into how competency develops in industry (and what competence is) that an understanding of the role of experience in training has begun to emerge, although this does not seem to have been appreciated by either industrialists or educators. However, from the perspective of this discussion if change and particularly big change is to be introduced there has be a knowledge base that is understood by the participants such that they can construct scaffolds that will enable the change to take place. This knowledge base helps to make the change 'plausible'. A curriculum that does not appear to be 'plausible' is unlikely to be approved by the authorities as happened at the University of Lancaster in the late nineteen sixties.

Knowledge began to become available in the early 1960's and in the middle nineteen sixties the Vice-Chancellor of the University of Lancaster sought the advice of industrialists, including G. S. Bosworth about the type of engineering curriculum that the University should develop. The appropriate sub- committee of the University Grants Committee (Bosworth was a member) had made it clear that it thought that there was no further need for traditional subject approaches in civil, electrical and mechanical engineering. The vice-Chancellor asked a small group of industrialists and educators to come up with proposals. Their study, influenced by recent developments in educational thinking, produced a curriculum for design and manufacture that had a cooperative element with industry, and elements of both project based and problem based learning in the areas of engineering analysis and engineering synthesis [24]. The original submission by the Vice-Chancellor was rejected by the Senate on the advice primarily of the science professors whose understanding of engineering was of a traditional group of applied sciences. The model was not 'plausible' [25]. There was some evidence that the subject committees of the NCTA that evaluated dip.tech syllabuses were influenced by traditional approaches.

Applied generally to higher education this case study shows that attention has to be made to all the components of the sub-system and the system in which it exists if radical change is to be achieved. Power to influence developments is widely distributed. Change will not take place unless all the actors perceive it to be plausible and necessary. (It was not necessary for the firms supporting the dip.tech to continue to support it: there were other avenues they could use). Plausibility depends on the actors perceiving that there is a strong supporting knowledge base which will not change their benefit, or in the way that they benefit.

Appendix Notes and references

[1] Cuban, L (1987). Constancy and Change in Schools (1880's to the present) Conference on restructuring Education, Keystone, CO .See also Eggleston, J (1977). *The Sociology of the Curriculum*. London. Routledge.

[2] (1945*). Higher Technological Education. Report of a Special Committee Appointed in April 1944*. London, HMSO. (Known as the Percy Report after its chairman Lord Eustace Percy).

[3] Payne, G. L. (1960). *Britain's Scientific and Technological Manpower*. Stanford/London. Stanford and Oxford University Presses.

[4] *Technical Education* (1956). (Whitepaper Ministry of Education). London. HMSO Cmnd 9703). This proposed the restructuring of technical education into four tiers with Colleges of Advanced Technology at the Apex followed in descending order by Regional Colleges, Area colleges and Local Colleges. The terms Technologist, technician, craftsman and operative were defined. In theory it was intended that Regional Colleges would be primarily for technologist and technician training, Area colleges for technician and craft training, and Local colleges for craft and operative training.

[5] 'A' Level = Advanced level of the General Certificate of Education. An 'A' Level is an examination in a particular subject taken after two years of study in the sixth form (equivalent to years 11 and 12 in the U.S. system). More recently the 'sixth form' terminology has been replaced by year numbers as in the U.S.

University entrance required satisfactory performance (as defined by the University) in three 'A' levels. A engineering department might require performance in Maths, Physics and one other Science (e.g Chemistry). At the time these examinations were generally considered to be of the equivalent to the standard required at the end of the first year of an American University course. For a good description see [3] pages 134-138.

[6] In practice this intake was very much smaller. A good Ordinary National Certificate (ONC) was taken to be the equivalent of the Advanced ('A') Level of the General Certificate of Education. Several reports at the time showed that these students as a group performed as well as the 'A' level group (e.g Dickenson, H (1964) Students in a CAT. Qualification and success. *Universities Quarterly*, 18, 407-414. See also ref 16, pp 107-109. For a description of the national certificate system see ref 3 pages 201 – 210 which includes a section on City and Guilds Certificates.

[7] Heywood, J., Pollitt, J., and V. Mash (1966). The Schools and Technology. *Lancaster Studies in Higher Education*. No 1. April (University of Lancaster, Department of Higher Education).

[8] D. G. Hutchings (1963) in a report that made a major impact on policymakers showed that on average students entering the sciences did so with grades higher than those entering technological subjects. (Hutchings, D. G (1963). *Technology and the Sixth Form*. Oxford. Oxford University Institute of Education. See also Carter, G (1992). The fall and rise of university engineering education in England in the 1980's. *International Journal of Technology and Design Education*, 2(2), 2- 21.

[9] Ministry of Education (1957). Liberal Studies in Technical Colleges. Circular 323. London. HMSO.

[10] Davies, L (1965) *Liberal Studies and Higher Technology*. Cardiff. University of Wales Press. This is the most authoritative account of circular 323 and the development of liberal studies in the CAT's.

 Among the diplomates were those who considered that any liberal study should have relevance to their intended occupation. They valued subjects like economics, human relations, and industrial administration which Andrews and Mares called "tool/ fringe" subjects because they had some utility or semi-utility value in technological training 11]. In contrast "cultural" subjects added to the sensibilities of the students/. They noted that 50% who claimed to have benefited from liberal studies three quarters had referred to tool/fringe subjects and only 5% to "cultural" subjects. Overall 39% 0f the students and the same proportion of instructors favoured tool/fringe subjects whereas the heads of liberal studies departments favoured both types of subject with a bias in favour of the cultural [10, p 80]. They also interviewed industrialists and those who commented took a utilitarian view of what should be studied. Their results led them to suggest that the syllabus (content) should fall into four main divisions –language and communications, technical studies, social studies and optional. Their model differed

little from that proposed by Grinter in his report to the American Society for Engineering Education [11(a)], or Gerstl and Hutton in their report to the Institution of Mechanical Engineers [11(b)].

(a) Grinter, L et al (1955). Final report on evaluation of engineering education. *Journal of Engineering Education* September pp 26 – 60.

(b) J. Gerstl. J. E and S. P. Hutton (1969). *Engineers. The Anatonmy of a Profession*. London. Tavistock.

[11] Andrews, H and C. Mares (1963).Liberal Studies in Advanced Scientific and Technological Courses. In Heywood, J and R. Ann Abel (eds). *Technical education and Training in the United Kingdom. Research In Progress 1962 – 64*. National Foundation for Educational Research, Occasional Publication No 8, Slough. (see reference 7 pp 79 – 83)

[12] The comparability of standards was never tested by the committee. It was assumed that the *propter hoc* evaluations by the NCTA indicated degree level (i.e. buildings of appropriate standard, course content vetted by NCTA committees, and the use of external examiners most of whom came from the universities. In one study of a small sample of external examiners it was concluded that they believed the courses corresponded with similar course in the universities [13]

[13] Heywood, J (1969). An Evaluation of Certain Post-War Developments in Higher Technological Education. Thesis. Lancaster. University of Lancaster.

[14] *Higher Education* (1963). A report of a committee chaired by Lord Robbins. London. HMSO. Cmnd 2165.

The committee recommended that the NCTA should be replaced by a Council for National Academic Awards (CNAA) that would have the power to sanction degree programmes in any subject in a group of technical colleges. These were given the title of Polytechnics. In 1992 they followed the CATs and were recognised as universities (commonly called the 1992 universities).

[15] Heywood, J (2011). Developments in higher technological education in England and Wales between 1955 -1966. The Contribution of the British Electrical Engineering Industry. *Proceedings Annual Conference of the American Society for Engineering Education*. June, Vancouver.

[16] The Principal of Birmingham College of Advanced Technology (Sir Peter Venables) believed that if his college adopted the end-on arrangement it would double the number of students. He was persuaded by a college working group on the problem to seek finance for an investigation into the effectiveness and in consequence the spacing of sandwich courses. The Nuffield Foundation agreed to fund the study which had been designed by Dr Tom Lupton, Head of the Department of Industrial Administration. The paragraphs in this report on the period 1945-1966 are based on the reports of that study [see ref 13].

[17] *loc.cit* ref 13.

[18] British Association for Commercial and Industrial Education (BACIE) Annual conference.

The data was subsequently published in 1974 in Heywood, J (1974). Trends in the supply and demand for qualified manpower in the sixties and seventies. *The Vocational Aspect of Education*, 26, (64), 65 – 72, 1974.

[19] *loc.cit* ref 15 The Chairman of the Committee was Sir Lionel Russell, Chief Education Officer of the Birmingham Local education Authority.

[20] Bosworth, G. S (1963). Towards creative activity in engineering. *Universities Quarterly*, 17, 286.

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

[22] *The Proceedings of the Institution of Mechanical Engineers* (179(4) Pt 1 includes two papers one on university projects [22 (a -99)] and the other on projects for the dip.tech [22(b) pp 100- 112)] together with the discussion (pp 113 – 121) and written communications (pp 121-1340 which give an account of developments

by 1964-65.The focus was on the teaching of design which many in the university system perceived either to be not teachable or difficult [22(c)]

(a) Hayes, S. V. and S. A. Tobias. The project method of teaching creative mechanical engineering.

(b) Pullman, W. A. Teaching design to sandwich course students.

(c) Bishop, R. E. D. (1963). On the teaching of design in Universities. Proceedings Institution of mechanical Engineers. 177, 719.

[23] Jahoda, M (1963). *The Education of Technologists*. London, Tavistock.

[24] Heywood, J., Lee, L. S., Monk, J. D., Moon, J., Rowley, B. G. H., Turner, B. T and J. Vogler (1966). The Education of professional engineers for design and manufacture (A Model Curriculum). *Lancaster Studies in Higher Education*, April, No 1. 2 – 151.

A substantial review appeared in *Engineering*, 29th April 1966, pages 800 and 801. This can be read in conjunction with a quite different description in Heywood, J (2005). *Engineering Education. Research and Development in Curriculum and Instruction.* Hoboken, NJ. IEEE Press/Wiley.

[25] Heywood, J (2006). Factors in the adoption change: Identity, Plausibility and power in promoting educational change. *ASEE/IEEE Proceedings Frontiers in Education Conference*, T1B, 9-17.
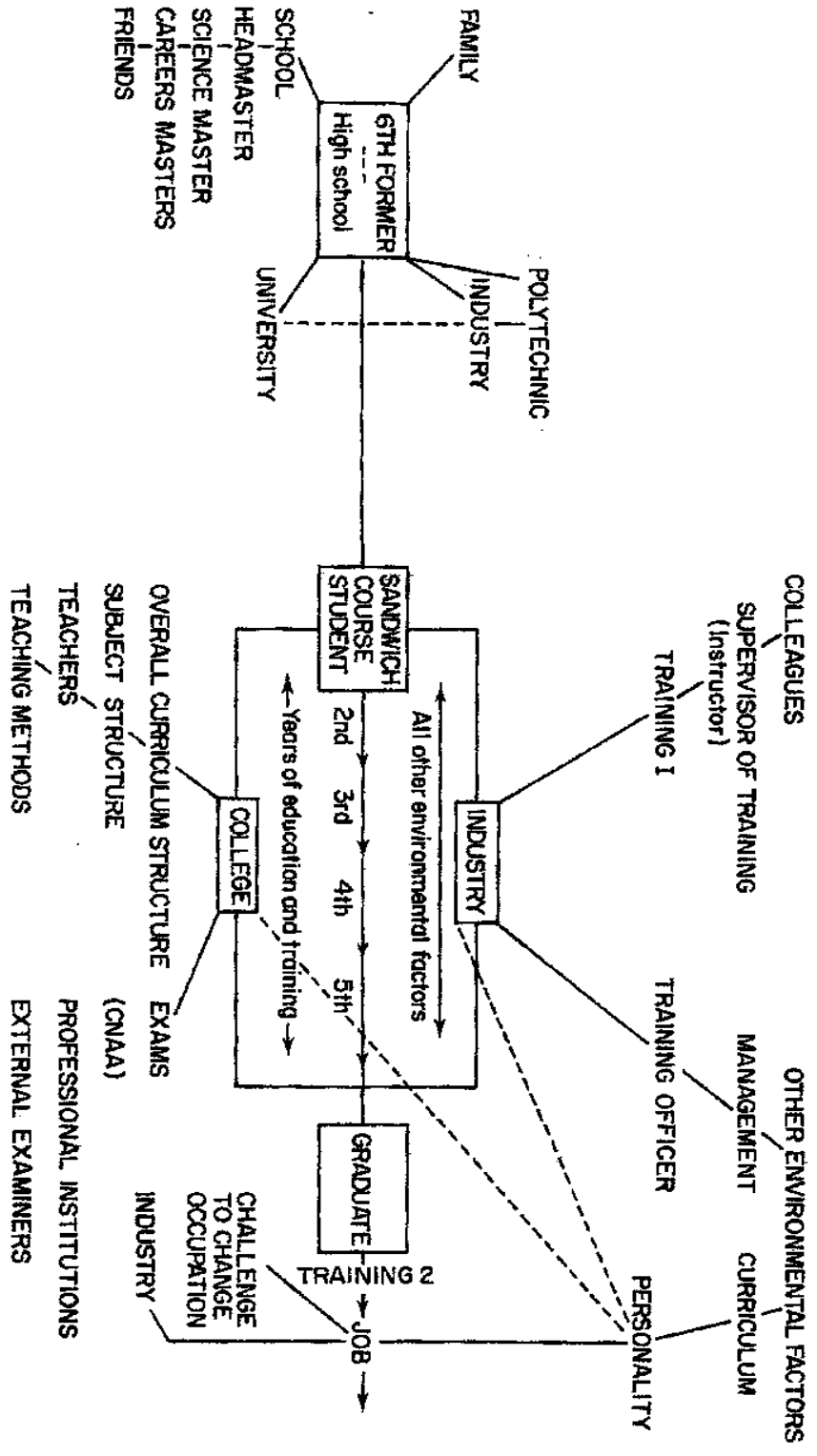
FAMILY

6TH FORMER
High school

SCHOOL
HEADMASTER
SCIENCE MASTER
CAREERS MASTERS
FRIENDS

UNIVERSITY

INDUSTRY

POLYTECHNIC

COLLEAGUES
SUPERVISOR OF TRAINING
(Instructor)

TRAINING 1

MANAGEMENT

OTHER ENVIRONMENTAL FACTORS

CURRICULUM

SANDWICH
COURSE
STUDENT

All other environmental factors

← Years of education and training →

2nd   3rd   4th   5th

INDUSTRY

TRAINING OFFICER

PERSONALITY

COLLEGE

OVERALL CURRICULUM STRUCTURE

SUBJECT STRUCTURE

TEACHERS

TEACHING METHODS

EXAMS
(CNAA)

PROFESSIONAL INSTITUTIONS

EXTERNAL EXAMINERS

GRADUATE

TRAINING 2

CHALLENGE
TO CHANGE
OCCUPATION

INDUSTRY

JOB

Figure 1A

Notes and references (main text)

[1]   Akers, B and M. M. Chingos (2016). *Game of Loans. The Rhetoric and Reality of Student Debt*. Princeton. Princeton University Press.

[2]   Erixon, F and B. Weigel (2016). *The Innovation Illusion. How so Little is Created by so Many Working so Hard*. New Haven. Yale University Press. p 205 cites the US Bureau of Labor Statistics and US Bureau of Economic Analysis and includes graph.

[3]   *loc.cit* ref 1.

[4]   Curriculum drift is a term developed in the UK to describe how the curriculum focus moved away from a focus on the production of engineers for industry to mirror that offered in university engineering and technological studies by Colleges of Advanced Technology in the late 1950's and early 1960's. In general educational institutions seek higher status by mirroring the institution above them in the status tree. (See appendix)

[5]   Goldrick-Rab, s (2016). *Paying the Price: College Costs, Financial Aid, and the Betrayal of the American Dream*. Chicago. University of Chicago Press cited by Foroohar, R (2016) How the financing of colleges may lead to disaster. *New York Review of Books*, October 13th. See also review by Laurie Taylor from the perspective of a UK academic https://www.timeshighereducation.com/books/review-paying-the-price.

[6]   Foroohar, R (2016). *Makers and Takers. The Rise of Finance and the fall of American Business*. New York. Crown Business/Penguin Random House

 Describes a change in the role of banks from funding new investment to lending against existing assets thereby creating economies based on debt. For a UK view [(a)]. For another US view [(b)]

(a). Turner, A (2016). *Between Debt and the Devil. Money, Credit, and Fixing Global Finance*. Princeton, NJ. Princeton University Press.

(b) Reich, R. B (2016). *Saving Capitalism for the Many, Not the Few*. New York. Alfred A. Knopf.

(c) For a mapping of the system with an illustration of the Bear Stearns collapse see Bookstaber, R and D. Y. Kenett (2016). Looking Deeper, Seeing More: A multilayer map of the financial system. OFR Brief Series. 16-06 July 14 2016. Washington DC. Office of Financial Research.

 [7]   Foroohar also takes this position in a book review. How the financing of colleges may lead to disaster. New York Review of Books, October 13th 2016. See chapter 3 of C. O'Neil 92016) *Weapons of Math Destruction. How Big data Increases Inequality and Threatens Democracy*. London. Penguin Books. describes the impact of rating scales on the development of American Universities .For a description of similar developments in the U.K. see Hale, T and G Vina (2016) University challenge. The race for money students and status. FT magazine 27/06/2017. https://next.ft.com/content/c662168a-38c-11e6-a780-b48ed7b6126f.

 [8]   Foroohar, R (2016) How the financing of colleges may lead to disaster. *New York Review of Books*, October 13th 2016.

[9]   *loc cit* ref 6(b)

[10]   Autor, D. H. (2015). Polyani's Paradox and the shape of employment growth *In Re-evaluating Labor Market Dynamics* pp 129-79. Kansas City. Federal Reserve Bank of Kansas City.

[11]   Career Vision. Opportunities Abound in Middle Skill Jobs. https://careervision.org/opportinities-abound-middle-skill-jobs Accessed 14th August 2017. Provides links to U.S. Department of Labor and Bureau of Labor Statistics.

[12]   Carnevale, A. P., Rose, S. J., and B. Cheah (2011). *The College Payoff, Occupations, Lifetime Earnings*. Washington, DC. Georgetown University Center on Education and the Workforce.

[13]   Goodwin, B (2012). Research says/ don't overlook middle skill jobs. *Educational Leadership*. 89(7), 86-87.

[14]   See chapter 4 of O'Neil *loc.cit* note 7.

[15]   *loc.cit*. ref 7.

[16]   Sparks, E and M. J. Waits (2011*). Degrees for What Jobs? Raising Expectations for Universities and Colleges in a Global Economy.* Washington, DC. National Governors Association.

[17]   Heywood, J (2012). Education at the crossroads: Implications for Educational Policy Makers. Distinguished Lecture at annual conference of the American Society for Engineering Education.

[18]   Harari, Y. N (2017). *Homo Deus. A Brief History of Tomorrow*. Dvir Publishing.

[19]   Tegmark, M (2017*). Life 3.0. Being Human in an Age of Artificial Intelligence*. ISBN-10:1101946598

[20]   Heywood, J (2014). Engineering Education in Search of Divergent vision. Who am I? Who are you? Where are we going? Keynote Address 44th Annual ASEE/IEEE Frontiers in Education Conference, Madrid.

"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 [a]. 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 [b]. 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 [c]. 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 [d] […]"

[a]. 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."

[b]. 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.

[c]. 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.

[d]. 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."

(e) Avent, R in a special report in *The Observer* 9/10/2016 Welcome to a World without Work writes, "It (work) is also a source of personal identity. It helps give structure to our days and our lives. It offers the possibility of personal fulfilment that comes from being of use to others and it is a critical part of the glue that holds society together and smooths its operation. Over the last generation work has become ever less effective at performing these roles. That in turn, has placed pressure on government services and budgets, contributing to a more poisonous and less generous politics".

[21] Rawnsley, A (2017). You don't need a double first to see university funding is in chaos. *The Observer*. 09:07:2017. P 35.

[22] Social Market Foundation (2017). *On Course for Success? Student Retention at University*. London. Social Market foundation.

[23] Britton, J., Dearden, L., Shephard, N., and A. Vignoles (2016) *How English domiciled graduate earnings vary with gender, institution attended, subject and socio-economic background*. IFS Working Paper W16/06. London. Institute of Fiscal studies.

[24] Kemp-King, S (2016). The Graduate Premium: Mann, Myth or plain mis-selling? London. Intergenerational Foundation.

[25] King, I (2017). The lessons from rising student loan debt have not been learnt. The *Times*, 25:07:2017. p 36

[26] Two-year university courses come a step closer. 24:02:2017. https://www.gov.uk/government/publications/amendments-tabled-ahead-of-lords-report-stage

[27] Russell, J (2017). Students are getting a third class education. many universities don't care about teaching quality and undergraduates don't realise it until it's too late. *The Times* 23:03: 2017 p 18.

[28] Bennett, R (education editor) Students taught one to one for only 26 hours in entire degree. *The Times* 31:07: 2017. p 18. This article is about a study of contact hours in UK universities. The authors of that report have a separate article in the same issue. Huxley, G and M. Peacey. Tuition fees must be linked to quality.

Russell group. A grouping of UK universities not including Oxford and Cambridge intended to form an élite.

 [29] Johnes, G and J. Johnes (2016). Costs, efficiency, and economies of scale and scope in English higher education. *Oxford Review of Economic Policy*, 32(4), 596-614.

[30] Holmes, C and K. Mayhew (2016). The economics of higher education. *Oxford Review of Economic Policy*, 32(4), 475-496.

[31] Chambliss, D and C. Takacs (2014). *How College Works*. Cambridge. MA. Harvard University Press.

[32] *loc.cit* ref 30.

[33] Milton, O., Pollio, H. R., and J. A. Eison (1986). *Making sense of College Grades*. San Fransico, CA. Jossey-Bass. The period investigated was 1950-1965.

[34] CIPD (2015). *Over-qualification and Skills Mismatch in the Graduate Labour Market*. Policy report. London. Chartered Institute of Personnel Development.

 An EU analysis that shows that apart from five countries the UK has a higher underutilisation rate than the other members of the EU 27. The authors note that much research in this area confuses by conflating two issues-whether a degree is necessary to get a job, and whether it is needed to do the job.

[35] *loc.cit* ref 30.

[36] 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."[a] But Teitelbaum went on to argue that such data that was available was weak and often misinterpreted [b]. 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." [c]. 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 [d]. Of course it may not be true of other countries [e].

Much the same applies to the U.K. In 1961 the Advisory Council on Scientific Policy published a controversial report which said that by 1965 the supply and demand for scientific manpower should be in balance which caused a huge row (f). In 1963 the Council changed its emphasis and argued that employers of mechanical engineers should be employing more qualified personnel (g). Heywood caused a stir at the 1963 annual conference of the British Association for Industrial and Commercial Education (BACIE) when he argued that on data obtained from employers he found no evidence of a shortage of qualified personnel (h).(See appendix)

[a] (a) Teitelbaum, M. S (2003) Do we need more scientists ? *The Public Interest*. No 153. National Affairs Inc Washington DC. He presented this paper at a 2007 conference on *The US Scientific and Technical Workforce. Improving data for Decision Making*. Organized by Rand Science and Technology. The Proceedings were edited by Kelly, T. K., Butz, W. P., Carroll, S., Adamson, D. M and G. Bloom. pp 11-31. It is interesting to note that forty three years ago John Jewkes in the UK asked a similar question," how much science?" In his Presidential address to the economics section of the British Association. (*Advancement of Science*, 67, 1960).

 (b) Lowell, B. Lindsay and H. Salzman (2007). *Into the Eye of the Storm: Assessing the Evidence on Science and Engineering Education, Quality, and Workforce Demand*. Urban Institute. 48 pages. Also considers that there is no shortage of scientists and engineers and examines in detail the perceptions that have led to the opposite view.

[c] Cited in *First Bell. Today's Engineering and Technology News* under the heading, Labor researchers tell Congress U.S. not lacking in scientists, engineers. ASEE, Washington, DC. See also (a) *First Bell* 07:06:2011 Some experts say STEM crisis is overblown and contrast with 21:10:2011, Demand for STEM skills increasing, study finds. (b) Patel, P (up dated 2010) Where the engineering jobs are.Tthe news is good but not great for engineers looking for work in 2010. *IEEE Spectrum* Downloaded 03:01:2012

[d] For example, (a) *First Bell* reports on 28:10:2009, High-achievers defect from STEM fields, study finds:23:05:2011, experts voice concern over high STEM dropout rate:16:06:2011, training programs

offer pointers on incorporating STEM into lessons: 03:02: Technology, engineering overlooked when STEM education discussed, teacher writes (in London *The Times* 01:03: 2012 in an article on the importance of science to Britain's recovery no mention is made of engineering): 08:02:2012, Obama to request $80 Million for education funding for training math, science teachers: 13:02:2012, Labor Department official discusses importance of STEM at the University of Dayton.

Ellis, R. A. (2007) *Effects of recent revisions in Federal Standard Occupational Classification (SOCCategories of the Employment of STEM Professionals*. New York. Commission on Professionals in Science and Technology.

Future of STEM Curricula and Instructional Design. A Blue Sky Workshop. December 1 – 3, 2009. Center for the Study of the Mathematics Curriculum.

(e)) Blau, J (updated 19:08:2011) Germany faces shortage of engineers. *IEEE Prism* Downloaded 03:01:2012. Also Schneiderman (2010) Economy and shortages affect European job outlook. The bigger high-tech companies in Europe are recruiting EE's. talent is in short supply, especially to smaller firms looking for very specific skills. *IEEE Spectrum*. March.

[f] Advisory Council on Scientific policy. Committee on Scientific Manpower (1961). *The Long Term Demand for Scientific Manpower.* London. HMSO, Cmd 1490.

[g] Advisory Council on Scientific policy. Committee on Scientific Manpower (1963). *Scientific and Technological Manpower in Great Britain 1962*. London. HMSO, Cmd 2146.

[h] Heywood, J (1974). Trends in the supply and demand for qualified manpower in the sixties and seventies. *The Vocational Aspect of Education*, 26, (64), 65 – 72

The section on Teitelbaum to ref (e) is taken from Heywood, J (2012). The response of higher and technological education to changing patterns of employment. *Proceedings American Society for Engineering Education*. June 2012.

Teitelbaum [i] clarified his thinking in a substantial treatise in 2014. He summarises his findings as follows:

- "First that the alarms about widespread shortages or shortfalls in the number of US Scientists and engineers are quite inconsistent with the available evidence.
- Second that the similar claims of the past were politically successful but resulted in a series of booms and busts that did harm to US science and engineering and made careers in these fields increasingly unattractive: and
- Third that the clear signs of malaise in the US science and engineering workforce are structural in origin and cannot be cured by simply providing additional funding. To the contrary recent efforts of this kind have proved to be destabilizing, and advocates should be careful what they wish for." [i. p 3].

[i] Teitelbaum, M. S (2014) *Falling Behind: Boom, Bust and the Global Race for Scientific Talent*. Princeton, NJ. Princepton University Press.

[37] The term "technologist" is used in British official documents instead of "engineer" but it mostly refers to "engineer."

[38] Advisory Council on Scientific policy. Committee on Scientific Manpower (1961). *The Long-Term Demand for Scientific* Manpower. London. HMSO, Cmnd 1490.

[39] Advisory Council on Scientific Policy, Committee on Scientific Manpower. *Scientific and Technological Manpower in Great Britain 1962*. London. HMSO, Cmnd 2146.

[40] *loc.cit* ref 36(i).

[41] Charette, R. N (2013). The STEM crisis is a myth *IEEE Spectrum*. International. 41- 52. September 2013. Spectrum.IEEE.ORG.

[42] *loc.cit* ref 36(i).

[43] *loc.cit* ref 41.

[44]   *loc.cit* ref 36(i) p 57

[45]   *loc.cit* ref 36(i) Ch.5.

[46]   *Professional Manager* ,2011, Winter issue, p 12. (Chartered Management Institute).

[47]   See Becker, S.F (2010). Why don't young people want to become engineers? Rational reasons for disappointing decisions. *European Journal of Engineering Education*, 35, (4), 349 – 366.

[48]   Schneiderman (2010) Economy and shortages affect European job outlook. The bigger high-tech companies in Europe are recruiting EE's. Talent is in short supply, especially to smaller firms looking for very specific skills. *IEEE Spectrum*. March. See also First Bell 12: 03: 2010. US facing shortage of nuclear scientists, engineers. 19:09:2007. Energy experts warn of worker shortage in Southeast US. 14:01:2008. Hewlett-Packard CEO warns of lack of US- trained engineers. 05:03:2008. Aerospace defense industries brace for worker shortages. 30:07:2008. Engineer shortage threatens oil supply growth, says oil executive.

[49]   Corinna Wu (2011) *ASEE Prism*, November p 40.

[50]   *The Professional Manager*, Winter 2011. Chartered Management Institute.

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

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

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

[54]   *loc.cit* ref 37.

[55]   Irwin, Neil (2017). To understand inequality consider the janitors at two big companies then and now. The Upshot September 3rd 2017. The New York Times. The companies contrasted are Eastman Kodak and Apple. The article gives a very good idea of the different cultures. This writer worked in firms with cultures similar to Eastman Kodak in the 1950's.

[56]   Cheville, R. A (2016). Linking capabilities to functioning adaptive narrative from role playing games for education. *Higher Education* 71, 805-818. DOI 10 1007/s 10734-015-9957-8

[57]   Susskind, R and D. Susskind (2015). *The Future of the Professions. How Technology will Transform the Work of Human Experts*. Oxford. Oxford University Press.

[58]   Bloomberg. August 30th 2017. These robots are using static electricity to make NIKE Sneakers. Describes a robot developed to make the uppers of Sneakers that has the effect of reducing the work force considerably. In a Nike making factory in China the average employment is about 1300. In a plant designed for the robots it is 130.

[59]   Patel, P (2017). Millennials are concerned automation will reduce their job prospects the I*nstitute* (The IEEE news Source) 10th May 2017.. IEEE.org (http://ieee.org). cites Deloitte Millenial Survey (https://www2.delloite.com/global/en/pages/about-deloitte/articles/millenialsurvey.html). See also- automation(http://theinstitute.ieee.org/ieee-roundup/blogs/blog/will-automation-kill-or-create-jobs)

 [60]   *loc.cit* ref 57.

[61]   *loc.cit* ref 57.

[62]   Autor, D. H (2015) Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives*, 29(3), 3-30.

[63]   *ibid.*

[64]   Brynjolfsson, E and A. McAfee (2011). *Race Against the Machine*. Lexington MA. Digital Frontier Press.

[65]   *Information Technology and the U.S. Workforce. Where are and Where Do We Go from Here?* (2015. A report of the National Academies of Sciences, Engineering medicine. Washington, DC. National Academies Press.

"Because most jobs involve multiple subtasks, and because technology typically targets specific tasks, one common impact of technology is to shift the distribution of tasks the human worker performs in a job (e.g., authors today spend less time proof reading for incorrect spelling enabling them to spend more time on the content of what they are writing). Technology also makes new tasks and new jobs possible transforming the nature of work in many, and ultimately most, industries" (p138).

[66] For example, Ridley, M (2016). Let's stop being so paranoid about androids. Pessimists have always warned that automation will abolish everyone's job, yet it continues to improve our lives. *The Times*, November 21st.

[67] *loc.cit*. ref 62.

[68] *loc. cit*. ref 62

[69] Holzer, H.J (2015). *Job Market Polarization and U.S. Worker Skills. A Tale of Two Middles*. Washington, DC. Brookings Institution. Economic Studies Working Paper, April 6.

[70] Karsten, J and D. M. West (2017) Can augmented reality bridge the manufacturing skills gap? Brookings 21/08/2017. https://www.brookings.edu/blog/techtank/2017/08/10can-aygmented-reality-bridge-the-manufacturing-skills-gap/?utm_campaign=Center%20for%20Technolog...

[71] OECD (2015) Science, technology and industry. Scoreboard 2015. Paris. OECD Publishing. http://dx.doi.org/10.1787/empl outlook-2015-en.

[72] OECD. Policy brief on the future of Work. *Skills for a Digital World.* Paris. OECD

[73] Matthews, M (2011). Editorial, November 2011. *ASEE Prism*.

[74] 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.

[75] *ibid* pp 22, 23, 26, 27. Minnesota Measures: 2009. Report on Higher education. Minnesota Office of Higher Education

[76] 04: 01: 2010 *First Bell* programs touted as helping students prepare for middle skill level jobs.

[77] Occupational Outlook Handbook. U.S. Bureau of Labor Statistics. Fast growing Occupations. Also Most New Jobs. Published together 17th December 2015.

[78] *loc.cit* ref 12.

[79] Goodwin, B (2012).Research says/Don't overlook middle skill jobs. *Educational Leadership*, 69(7) provides a brief review.

[80] *loc.cit* ref 7.

[81] Baker laments 'snobbery' against technical colleges. *The Times* 30th January 2017. But the colleges sponsored by Lord Baker are controversial. See Gove, M. My lesson from the latest schools scandal. *The Times* 10th February 2017.

[82] Career Vision. The Ball Foundation https://careervision.org/opprtunities-abound-mioddle-skill-jobs. Accessed 14:08:2017.

[83] *ibid.*

[84] Rosenbaum, J (2001). *Beyond College for All: Career Paths for the Forgotten Half*. New York; Russell Sage Foundation. Cited by Goodwin ref 79

[85] Acemoglu, D and P. Restrepo (2017). Secular stagnation? The effect of aging on economic growth in the age of automation.Working Paper 23077. http://www.nber.org/papers/w23077. Cambridge, MA. National Bureau of Economic Research.

[86]   Acemoglu, D and P. Restrepo (2017). Robots and jobs: evidence from US labor markets.Working paper 23285. http://www.nber.org/papers/w23285. Cambridge, MA. National Bureau of Economic Research.

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

[88] The terms are taken from J. Guilford's theory of creativity where divergent as contrasted with convergent thinking is often taken as the base for creative thinking. See Gregory, S. A. and J. D. Monk (1972). Creativity: definitions and models in S. A. Gregory (ed) *Creativity in Innovation and Engineering*. Butterworths, London.

[89] Aligning Technology and Talent development. Recommendations from the APLU and NCMS Expert Educator Team. Report 1. Summer 2017. Association of Public Land Grant Universities and National Center for Manufacturing Services in association with Lightweight Innovation for Tomorrow (LIFE) Manufacturing Institute.

[90]   Heywood, J (1969) An Evaluation of Certain Post-War Developments in Higher Technological Education. Lancaster. Thesis. University of Lancaster Library. Two Volumes.

[91]   Bloom, B et al (eds) (1956). *The Taxonomy of Educational Objectives. Vol I Cognitive Domain*. New York. David Mackay.

[92]   Joint Matriculation Board (1973). *Notes for the Guidance of Schools. GCE Engineering Science (Advanced)*. Manchester. Joint Matriculation Board.

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

[94]   Trevelyan, J (2014). *The Making of the Expert Engineer*. London CRC Press/Taylor and Francis.

[95]   Humble, W cited by Heywood, J (1970) qualities and their assessment in the education of technologists. *International Journal of Mechanical Engineering Education,* 9, 5-10.

[96]   Krathwohl, D., Bloom, B., and B. B. Mersia (1964). *Taxonomy of Educational Objectives. Vol 2. Affective Domain.* London. Longmans Green. See also Kaplan, L (1978). *Developing Objectives in the Affective Domain.* San Diego, CA. Collegiate Publishing.

[97]   Sternberg, R. J (1985). *Beyond IQ. A Triarchic Theory of Intelligence*. New York. Cambridge University Press.

[98]   *ibid*

[99]   Green, S (1990). *Analysis of Personal Transferable Skills Requested by Employers in Graduate Recruitment Advertisements*. Mimeo. Sheffield. University of Sheffield. Personal Transferable Skills Unit,

[100]   SCANS (1992). *Learning a Living. A Blueprint for High Performance. A SCANS Report for America 2000*. Washington, DC. Department of Labor.

[101]   Perry, W. G. (1970). *Forms of Intellectual and Ethical Development in the College Years*. New York, Holt, Reinhart and Winston.

[102]   King, P. M and K. S. Kitchener. (1994). *Developing Reflective Judgement*. San Fransisco, Jossey-Bass.

[103]   *loc.cit* ref 16

[104]   The term "vocational" is used a number of ways throughout the world. It is used to relate to particular careers that are said to be a "calling" e.g. nursing, the priesthood. It is also used as the opposite of academic to describe courses that rely on specialist techniques e.g. technicians, clerical officers. It is used in the second sense here.

[105]   Heywood, J (2016). *The Assessment of Learning in Engineering Education. Practice and Policy*. Hoboken, HJ. IEEE Pres/Wiley.

[106]   Carter, Sir Charles (1983) Great Expectations. Robbins III Charles Carter recalls the conventional wisdom of the report, *The Times Higher Education Supplement*. 4th November 1983. p 11.

[107]   Noddings, N (1995). *Philosophy of Education*. Boulder, CO. Westview Press

See also 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

[108]   Screening. An activity of sorting out contradictory aims described by Furst , E. J (1958). *Constructing Evaluation Instruments*. New York. Mackay. See also Heywood, J (1981). The academic versus practical debate. A case study in screening. *Institution of Electrical Engineers Proceedings* part A 128, 511-519.

 [109]   M. S. Schiro (1995). (2013). *Curriculum Theory. Conflicting Visions and Enduring Concerns*. 2nd edition. Los Angeles, Sage.

[110]   Cowan, J (2000). *On Becoming an Innovative University Teacher. Reflection in Action*. 2nd edition. Buckingham. SRHE/Open University Press.

[111]   Dewey, J. (1948). *Reconstruction in Philosophy*. Boston, Beacon Press.

[112]   Dewey, J. (1916). *Democracy and Education*. New York, Macmillan.

[113]   Postman, N. and C. Weingartner. (1969) *Teaching as a Subversive Activity*. New York, Delacorte Press.

[114]   Heywood, J (2017). In the press.

[115]   *loc.cit* ref 56.

[116]   Muller, J (2015). The future knowledge and skills in science and technology higher education. *Higher Education*, 70(3), 409-416.

[117]   Barnett, R and K. Coates (2004). *Engaging the Curricular in Higher Education*. Milton Keynes. Open University press.

[118]   Newman, J. H (1852/1923). *The Idea of a University Defined and Illustrated*. London. Longmans, Green

[119]   McGregor, D (1960). *The Human Side of Enterprise*. New York. McGraw Hill.

[120]   *loc.cit* ref 62.

[121]   Trist, E and W. Bamforth (1951). Some social and psychological consequences of the long wall method of coal cutting. *Human Relations*, 4, 3-38.

See also F. Emery (1969). In (ed) *Systems Thinking*. Harmondsowrth. Penguin.

[122]   Lanier, J (2013). *Who owns the future*? London. Allen Lane, Penguin.

[123]   Sternberg, R. J (1985) *Beyond IQ. A Triarchic View of Intelligence*. New York. Cambridge University Press.

[124]   Heywood, J (1989). *Learning, Adaptability and Change*. London, Paul chapman/Sage

[125]   Luchins, A. S (1942). Mechanisation in problem solving: the effect of 'Einstellung'. *Psychological Monographs* No 248. (It is sometimes called set induction).

[126]   Heywood, J (1992). Student teachers as researchers of instruction in the classroom in J. H C Vonk and H. J. van Helden (eds). *New Prospects for Teacher Education in Europe*. Free University of Amsterdam and the Association of Teacher Education in Europe, Brussels.

[127] Saupé, J (1961). Learning in P. Dressel (ed) *Evaluation in Higher Education*. Boston, MA. Houghton Mifflin.

[128] Glyn Price cited by Heywood, J (1989). *Assessment in Higher Education* 2nd edition. Wiley. Chichester.

[129] Kallenberg, B, J (2013). By Design. Ethics, Theology and the Practice of Engineering. Cambridge, UK. James Clarke.

[130] Dias, P (2013). The disciplines of engineering and history: some common ground. Science and Engineering Ethics. Springer. ISSN 1353-3452. Sci Eng Ethics DOI 10.1007/s11948-013-9447-2

[131] Heywood, J (2007). "Think… about how others think". Liberal education and engineering. *ASEE/IEEE Proceedings Frontiers in Education Conference*, T3C, 2 – 24. See Chapter 2 Heywood, J (2017). *The Human Side of Engineering*. .WWW.Morganclaypool.com.

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

[133] *loc.cit*. ref 93

[134] Thomas, B and C. Madigan (1974). Strategy and job choice after redundancy. A case study. *Sociological Review*, 22, 83-102.

[135] *loc.cit* ref 93.

[136] Senge. P (1990). *The Fifth Discipline. The Art and Practice of the Learning Organization.* New York. Doubleday.

[137] Foster, R (1986). *Innovation. The Attacker's Advantage*. London. Macmillan.

[138] Heywood, J (1989). *Learning, Adaptability and Change.* London. Paul Chapman

[139] Newman, J. H (1852). *The Idea of a University* (with additional lectures added in 1873. 1923 Impression). London, Longmans, Green. Discourse VI. Pp 124 – 150. Newman did not conceive of enlargement being caused by a wide range of knowledge though the study of a large number of subjects. […]"Liberal education is not mere knowledge, or knowledge considered in its *matter* […] whether knowledge, that is, acquirement, is after all the real principle of the enlargement, or whether that principle is not something beyond it". P 130. For a commentary see Culler, A. D. (1955). The *Imperial Intellect. A Study of Newman's Educational Ideal*. Yale University Press. Pp 204 – 208. The principles of Newman's theory of knowledge will be found in his University Sermons especially No 14.

[140] *The Idea* p138. Perhaps the most quoted paragraphs on this point end the seventh discourse pp 177 and 178 of *The Idea*. They read "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."

[141] Newman, J. H (1890) *Fifteen Sermons Preached before the University of Oxford*. 3rd ed. Rivingtons, London. 14th Sermon para 21 – p287.

[142] *ibid.*

[143] Saupé, J. L (1961) in P. Dressel (ed).. *Evaluation in Higher Education*, Houghton Mifflin, Boston. or see Heywood, J (1982). *Pitfalls and Planning in Student Teaching*. London, Kogan Page. P 14.

[144] *The Idea* p166 in Discourse VII Knowledge and Professional Skill.

[145] Transfer is related to critical/reflective thinking. See Heywood, J (2000) *Assessment in Higher Education. Student Learning, Teaching, Programmes and Institutions.* London, Jessica Kingsley. Section on the critical thinking movement in higher education pp 177 – 181 and 187 to 191.

[146] The argument was set out differently and in a little more detail in my paper (1505) on *Engineering Literacy: A Component of Liberal Education*, to the technological Literacy Division at Annual ASEE Conference 2010. Under the heading, Implications for the curriculum" it reads- Newman considered that all "[…] the branches knowledge are, at least implicitly the subject matter*"* of the university curriculum. Imparting this knowledge in a philosophical way gives a university its culture. This " culture is a good in itself; that the knowledge which is both its instrument and result is called Liberal Knowledge; […]" [a] It is a universal knowledge and the university is conceived of as a *Studium Generale* or a school of universal learning.

At issue is the meaning of "universal." Today we take it to mean "all inclusive" but as Culler pointed out this was not the case in Newman's time especially as it was used in the context of university education. At that time its usage derived from "*uni-versum*" and meant "*turned into one.*" There was, Culler writes - "a desire to see things whole that forced men to look at the whole body of things, and therefore the true character of a university is not that it teaches all the sciences but that whatever sciences it does teach, it teaches in a spirit of universality." [b]. But this does not mean that it can be done within a single specialism for each subject has something of its own that is specific to itself to offer. Newman wrote; "If we might venture to imitate […] Lord Bacon, in some of his concise illustrations of the comparative utility of the different studies, we should say that history would give fullness, moral philosophy strength, and poetry elevation to the understanding. […] the elements of good reason are not to be found fully and truly expressed in any one kind of study" […] moreover, " if different studies are useful for aiding, they are still more useful for correcting each other" […].[c]. Each study has its own characteristic way of thinking, and each subject makes its own contribution to our understanding, hence the importance of the skill of thinking. It is the argument for including engineering as a subject in the curriculum of general education.

Necessarily "man," who is at the centre of this aim has to be viewed in all his relationships. […] "What is true of man in general would also be true of any portion of reality however minute. If we wished to know a single material object-for example, Westminster Abbey-to know it thoroughly, we should have to make it the focus of universal science. For the science of architecture would speak only of its artistic form, engineering of its stresses and strains, geology of its stones, chemistry and physics of the ultimate constitution of its matter, history of its past and literature of the meaning which it had for the culture of a people. What each one of these sciences would say would be perfectly true to its own idea, but it would not give us a true picture of Westminster Abbey." [d]. So wrote Culler to further illustrate Newman's idea. To get a true picture the sciences would have to be recombined and this recombination is the object of university education. We might go further and add that it is through such recombinations that advances in thought and practicalities are made. But Newman did not think recombination was the same as all the subjects taken together. It "is a science distinct from them all and yet in some sense embodying the materials of them all." [e]. This activity is what Newman called liberal knowledge and at other times, as Culler notes, philosophy, *philosophia prima*, Architectonic science or Science of the Sciences. He did not pursue this concept in any great detail, but in the today's jargon it would seem to be a reflective activity of synthesis; an ability to bring all the parts together in order to make a judgement, for which reason the subjects of the curriculum cannot be taught as entities isolated from each other. The consequences of this capability for the educated person so produced were set down by Newman in the oft quoted statement about the ends of a university education given in note 10 above. This statement clearly shows the importance of development in the "affective" as well as the "cognitive domain." To gain such a comprehensive view, study of as wide a range of knowledge as is possible, this to include engineering, is necessary; but how is that to be achieved without some missionary activity and curriculum innovation, and at what level?

(a) *loc.cit* ref 139 p 214, Discourse IX. Duties of the church towards knowledge.

(b) Culler, A. D (1955) *The Imperial Intellect. A Study of Cardinal Newman's Educational Ideal*. Yale U.P. New Haven. P 180.

(c) *loc. cit* ref 139. p 175

(*d*) Culler's illustration is chosen over Newman's because of the reference to engineering, p 182 ref 11.

(d) *loc.cit* ref 24 (Heywood, 2005) p 182. In Newman ref 139 see pp 43 ff of the second discourse and the fifth discourse.

[147] (a) Zitner, A and D. Chinni (2016). Voters education level a driving force. *The Wall Street Journal* October 14th.

(b) Ferguson, N (2016). This was no whitelash, it was a vote to get America working. *The Sunday Times* 13th November.

[148] Gove, M (2016). 'Experts' like Carney must curb their arrogance. *The Times* 21st October.

[149] 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.

[150] *ibid*

[151] *ibid*

[152] (i) Davies, L (1965). *Liberal Studies and Higher Technology*. Cardiff. University of Wales Press.

(ii) Heywood, J (2011). Higher technological education in England and Wales, 1955-1966. Compulsory Liberal studies. *Proceedings Annual Conference of the American Association for Engineering Education*, Paper 635.

[153] Astin, A. W. (1993). *What Matters in College? Four Critical Years Revisited*. San Fransico. Jossey-Bass.

[154] *ibid*.

[155] Macmurray, J (1961). *Persons in Relations*. London. Faber and Faber.

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

[157] Lucey, C (2017). Downside of diversity is entrenched division. *The Times*, 1st September.

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

[159] loc.*cit*. ref 131

[160]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.

[161] Dertouzos, M. L. Lester, R. K and R. M. Solow and the MIT Commission on Industrial Productivity (1989). *Made in America. Regaining the Productive Edge*. Cambridge MA. MIT Press. (chapter 12).

[162] Heywood, J (1994). *Enterprise Learning and its Assessment*. Technical report No 20. Sheffield Learning Methods Branch, Employment Department. Exhibit 1.4 p 17.

[163] *loc.cit* ref 123.

[164] Ellis, W (1995*). The Oxbridge Conspiracy. How the Ancient Universities have kept their Stranglehold on the Establishment.* .London, Penguin.

[165]   Macfarlane Smith, I (1964). *Spatial Ability*. London. University of London Press.

[166] (a) Thomson, A (2017). An Apprentice can do better than a graduate. *The Times*. 1st February.

 (b) Purves, l (2017) Let's stop sneering at Blue-Collar careers. *The Times* 23rd January.

[167]   Tegmark, M (2017*). Life 3.0. Being Human in an Age of Artificial Intelligence*. ISBN-10:1101946598

He founded with support from such persons as Elon Musk and Stephen Hawking "The Future of Life Institute" (FLI).

[168]   Krupczak, J., Blake, J. W., Disney, K. A., Hilgarth, C. O. Libros, R., Mina, M., and S. R. Walk (2012)DefiningTechnological Literacy. *Proceedings Annual Conference American Society for Engineering Education*, Paper AC 2012- 5100. In one of their ways of distinguishing between the two,literacies they argued that "engineering literacy is viewed as having a focus directed more toward the process of creating technological artefacts or systems" and that "technological literacy includes a broader view of products or results of the engineering process as well as the relation between technology and society". Krupzcak et al acknowledge that the "extent to which engineering and technological literacy form a subset of each other remains a topic for future discussion and investigation". On the basis of a process/product view of the matter Krupczak et al argue that a person who is technologically literate would have a *"knowledge or ability to design, analyze or otherwise create the constituent parts of the…."*, and they give the example of the motor car. In respect of the broader view they say "technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society." Since "technology can be viewed as identifiable things that result from engineering or related work" it should therefore "include some knowledge of these concepts, systems and processes."

[169] Heywood, J (1986). Toward technological literacy in Ireland: opportunities for an inclusive approach in Heywood, J and P. Matthews (eds). *Technology, Society and the School Curriculum. Practice and Theory in Europe*. Manchester. Roundthorn Press.

 [170]   Bucciarelli, L. L (2003). *Engineering Philosophy*. Delft. Delft University Press. p101.

[171]   *ibid*

[172]   Practical intelligence and tacit knowledge.

Sternberg and his colleagues included within the domain of practical intelligence, practical problem solving, pragmatic intelligence and everyday intelligence

"Practical intelligence involves a number of skills as applied to the shaping of and selection of environments" (which Sternberg argued is what intelligent people do). "These skills include among others (1) recognizing problems, (2) defining problems, (3) allocating resources to solving problems, (4) mentally representing problems, (5) formulating strategies for solving problems, and (7) evaluating solutions to problems" (a).

Hedlund and Sternberg considered that what differentiates emotional from social and practical knowledge is "tacit knowledge." That is, the knowledge that is not taught, but acquired as part of everyday living. As Michael Polyani who identified this category of knowledge put it "We know more than we can tell" (b). The idea is vividly captured in Yorkshire dialect by the term "nouse!" [c] This knowledge is acquired from managing one's self, managing tasks, and managing others. It is as Trevelyan has shown of major importance in the practice of engineering (d).

A key skill in the development of tacit knowledge is self-reflection yet the Sheffield study found that engineering students do not like to self-reflect. "They were not used to talking in terms of feelings, nor could they see the relevance of such reflection to learning about engineering problems." Whether or not one should talk about one's feelings has become a matter of debate in the UK since Prince Harry revealed his difficulties that arose from the death of his mother this year.

"The ability to acquire knowledge, whether it pertains to managing one's self, managing others, or managing tasks can be characterized appropriately as an aspect of intelligence. It requires aspects such as encoding essential information from the environment and recognizing associations between new information and existing

knowledge. The decision to call this aspect of intelligence social, emotional, or practical intelligence will depend on one's perspective and one's purpose" (e).

(a)   Sternberg, R. J and E. L. Grigorenko (2000). Practical intelligence and its development in Bar-On, R and J. D. E. Parker (eds). *The Handbook of Emotional Intelligence*. San Fransisco. Jossey Bass.

(b|)   Polyani, M (1966). *The Tacit Dimension*. Garden City. Doubleday.

(c)   Nouse alternative Nous. Intuitive apprehension: common sense, practical intelligence, gumption (The New Shorter Oxford English Dictionary. Oxford University Press.

(d)   *loc.cit* ref ?. James Trevelyan writes that engineers should have "the ability to value, acquire, develop, and use tacit ingenuity which is compiled in a vast library in your mind composed of 'how to' fragments of unwritten technical and other knowledge. Your progress as a student depended on knowledge that you could write down in examinations, tests, quizzes, etc. In engineering, your progress depends much more on knowledge that is mostly unwritten, the kind that is carried out in your mind and the minds of other people. To acquire this knowledge, you may need to strengthen your ability to listen, read and see accurately." […] "You need to understand what engineering is, how it works and why it is valuable. Value is a multidimensional concept: economic value, namely making money for yourself and others, is just one dimension. Other include caring for other people, social justice, sustainability, safety social change, protecting the environment, security and defence […] "you won't be able to find your way without knowing the point from which you are taking off. You will need the ability to understand yourself and where you are today" [pp 43-44].

[173]   Macmurray, J (1957). *The Self as Agent*. London, Faber and Faber.p 21.

[174]   Costello, J. E (2002). *John Macmurray. A Biography* Edinburgh, Floris books. p 323.

[175]   *ibid* p 325. Costello summarise the full structure of personal logic as follows, 1.The Self is agent and exists only as agent. 2 The self is subject but cannot exist as subject. It can be subject only because it is agent. 3. The Self is subject in and for the Self as agent. 4. The Self can be agent only by being also subject.

[176]   *loc.cit* ref 158

[177]   *ibid*

[178]   *ibid*

[179]   I have used Whitehead's major concept of creativity to fit this argument but I think he would have agreed.. For Whitehead every concrete entity an individualization of the universal creative force that is his ultimate. See p 268 of Lowe, V (1990) *Alfred North Whitehead. The Man and his Work* Vol II. Baltimore, The Johns Hopkins University Press.

[180]   Heywood, J and H. Montagu Pollock (1977). *Science for Arts Students. A Case Study in Curriculum Development*. Guildford, Society for Research into Higher Education. Shows how a course was redesigned to enhance the motivation of students.

[181] The term educational connoisseurship comes from Elliot Eisner who suggests that the teacher has to acquire the skills of an art critic when judging his or her own performance. Engineers require the same skill as part of their tool kit. Eisner writes: "the consequence of using educational criticism to perceive educational objects and events is the development of educational connoisseurship. As one learns how to look at educational phenomena, as one sees using stock responses to educational situations and develops habits of perceptual exploration, the ability to experience qualities and their relationships increase. This phenomenon occurs in virtually every arena in which connoisseurship has developed. The orchid grower learns to look at orchids in a way that expands his or her perception of their qualities. The makers of cabinets pay special attention to finish, to types of wood and grains, to forms of joining, to the treatment of edges. The football fan learns how to look at plays, defence patterns and games strategies. Once one develops a perceptual foothold in an arena of activity-orchid growing, cabinet making, or football watching – the skills used in that arena, one does not need the continual expertise of the critic to negotiate new works, or games or situations. One generalizes the skills developed earlier and expands them through further applications" (from E. W. Eisner, 1979). *The Educational Imagination; On the Design and Evaluation of School Programs*. New Yiork, Collier MacMillan.

[182] Heywood, J (1989). *Learning, Adaptability and Change*. London, Paul Chapman/Sage.

[183] Bucciarelli, L. L (2003). *Engineering Philosophy*. Delft, DUP Satellite.

[184] Woodson, T. T (1966).*Introduction to Engineering Design*. New York, McGraw Hill.

[185]   Heywood, J (2005*). Engineering Education. Research and Development in Curriculum and Instruction*. Hoboken. NJ. IEEE/Wiley. Chapter 4.

[186] **First edition only**. Vardy, P and P. Grosch (1994). *The Puzzle of Ethics*. London, Font Paperbacks, Harper Collins.

[187] Kohlberg, L and E. Turiel (1971) Moral development and moral education. Lesser, G (ed). *Psychology and Educational Practice*. Chicago, Scott-Freeman.

[188] Haws, E. D (2001) Ethics instruction in engineering education: a (mini) meta-analysis. *Journal of Engineering Education,* 90(2), 223 – 231. There have of course been developments since then. See for example Bowen, W. R (2009) *Engineering Ethics. Outline of an Aspirational Approach*. London, Springer- Verlag.

[189] This may oversimplify Whitehead's general philosophy which is stated in *Process and Reality* (1929, New York, Macmillan). For different perceptions of that work see Honderich, T (ed) (2005). The Oxford Companion to Philosophy..p 957, Oxford UP. And Scruton, R (1994*). Modern Philosophy. A Survey*. Pp 372 - 374 London, Sinclair-Davidson52

[190] *loc.cit* ref 173.

[191] *loc.cit* red 174.

[192] *loc.cit* ref 167.

[193]   Bruner, J (1960). *The Process of Education*. New York, Vintage. Bruner considered the curriculum to be dynamic and evolving. In a course based on this principle the curriculum evolves through a process of discovery learning. It is reinforced by a spiral curriculum in which basic concepts are discussed at increasing levels of depth in different contexts and in which there is feedback between the levels.

[194] Marshall, T. H (1939) professionalism in relation to social structure and policy reprinted in Marshall, T. H (1963). *Sociology at the Crossroads and other Essays*. London, Heinemann.

In relation to the growing number of semi-professional institutions in the UK he wrote "an organized profession admits recruits by an impartial test of their knowledge and ability. In theory they are selected on merit, but it is merit of a particular kind which usually must be developed and displayed in a particular, prescribed way. A narrow road leads into the profession through certain educational institutions. How far this favours social mobility depends on whether those institutions are open to the masses, so that merit can win recognition in all classes. Granted that broadening of the educational ladder typical of modern democracies, the system of official examination is more favourable to mobility than one arbitrary appointment or casual promotion. But the chance to move comes early, during schools days. Once it has been missed and a career has been started at a non-professional level, the whole system of formal qualifications makes movement at a later stage well-nigh impossible."

"There is another point. In the church or the army, in law, or medicine, a man at the head of his profession is on top of the world. He admits no superiors. But many of these new semi-professions are really subordinate grades placed in the middle of the hierarchy of modern business organization. The educational ladder leads into them but there is no ladder leading out."

[195] Hanushek, E,A., Schwerdt, G., Woessmann, L., and L. Zhang (2017).general education, vocational education, and labor market outcomes over the lifecycle. *Journal of Human Resources*. 52(1), 48-87.

[196] Wolf, A (Baroness) (2016). *Remaking Tertiary Education. Can we create a system that is fair and fit for purpose?* Education Policy Institute. London, Kings College.

[197] *loc.cit*. ref 81.

[198]   Clark, B. R (1956). The "cooling Out" function in higher education. *American Journal of Sociology*, 65, 569.

[199]   *ibid*

[200]   Between a community college and the engineering school of Binghamton University.

[201] Between the Department of Mechanical Engineering at the University of Salford and a local technical college offering national certificate courses.

[202]   *loc.cit* ref 106.

[203] Transdisciplinary derives from the need to respond to a single complex, concrete problem that requires the assistance of several disciplines that give a variety of viewpoints to the solution of the problem which is not resolvable by a single discipline but requires the synthesis of a number of solutions. This definition has its origins in a 1973 OECD document which is summarised in (a) Heywood, J (2005*). Engineering Education. A Review of Research and Development in Curriculum and Instruction*. Hoboken, NJ. Wiley/IEEEE. For a discussion of various models of interdisciplinarity see (b) Fogarty, R (1993). *Integrating the Curriculum*. Pallatine Ill. IRI/Sky Publ.

[204] Zeidler, D. L (2014). STEM Education: a deficit framework for the twenty first century? A sociocultural socio scientific response. *Cultural Studies of Science Education* 2(9) ISSN 1871-1502. Cult Stud of Sci Eduic DOI 10.1007/s11422-014-9578-z.

This model comes close to the criteria discussed in this paper. It derives from the need to respond to deficit thinking in STEM-based initiatives:

"It is intellectually and developmentally restrictive to view scientific understanding within the bounds of STEM. In contrast however, it is fundamentally important for any student to be able to frame any STEM topic in a personal, thoughtful and meaningful context so as to allow for open inquiry, discourse and evidence- based reasoning. The ability to do so, we will find, requires a global perspective of scientific literacy that entails among other skills, the proclivity and ability to envision the role of sociocultural political context in which such topics reside. Understanding the situational nature of those contexts and the ability to conceptualize scientific issues in responsible ways requires the exercise of prudence, morality and character."

The model used by Zeidler to support his thesis is due to G. Yakman.

Yakman, G. M (2008). http://www.steamedu.com/2008_PATT-Publication.pdf   Cited by Zeidler, D. L (2014). STEM education: a deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education* DOI 10.1007/s11422-014-9578-z.. 26th June.

See also the SCANS report (ref 100) which shows how key competencies required for work can be integrated into the subjects of the school curriculum. Is summarised in details in Heywood, J (2008*). Instructional and Curriculum Leadership. Towards Inquiry Oriented Schools.* Dublin. Original Writing for National Association of Principals and Deputies.

[205] Heywood, J (2012). The response of higher and technological education to changing patterns of employment*. Proceedings of the Annual Conference of the American Society for Engineering Education*. June,

[206]   Heywood, J (2014) Engineering Education in Search of Divergent vision. Who am I? Who are You? Where are we going? Key Note lecture. 44th Annual ASEE/IEEE Frontiers in Education Conference, Madrid.

[207] *ibid*