CUSTOMER SATISFACTION WITHIN EDUCATION – THE APPLICATION OF AN INTEGRATED CURRICULUM DESIGN METHOD.

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DECLARATION

I declare that the work submitted is the result of my own investigation. It has not been accepted for any other degree nor is it currently submitted in candidature for any other degree**.**

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ABSTRACT

The post-16 stage of education is critical in securing and developing people entering engineering professions and related occupations. Engineering employers and employees alike have however highlighted problems regarding poorly designed curricula failing to prepare employees for industrial and commercial roles.

The premise of this thesis is that the issue confronting education is one of quality management. Curriculum designers must know how to anticipate and understand customer requirements and practically translate these requirements into a deliverable curriculum package. The aim of this research is to realise the synergy of curriculum design and TQM by developing a theoretical integrated curriculum design method. Synergies between TQM and traditional curriculum design methods are investigated and an integrated curriculum design method based on the use of PDCA and incorporating a two-phase modified use of QFD is hypothesised and justified.

Subsequently, application of the curriculum design method is completed in relation to a number of selected engineering companies within the South Wales region and an appropriate curriculum proposal, for the provision of engineering education within the 16-18 year age group is produced. The proposal has been constructed with characteristics complementary to the competencies required by these companies and incorporates the most suitable teaching, learning and assessment methods to maximise the development of the students. This is valuable information for those concerned.

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GLOSSARY OF TERMS

AMA	Advanced Modern Apprenticeships.
APL	Accreditation of Prior Learning.
BPR	Business Process Reengineering.
CAD	Computer Aided Design.
CAM	Computer Aided Manufacture.
CBI	Confederation of British Industry.
CNC	Computer Numerical Control.
DfES	Department for Education and Skills.
DMAIC	Define, Measure, Analyse, Improve and Control.
DoE	Design of Experiments.
DTI	Department of Trade and Industry.
EFQM	European Foundation for Quality Excellence Model.
EMTA	Engineering and Marine Training Authority.
EU	European Union.
FE	Further Education.
FEDU	Further Education Development Unit.
FHEC	Framework for Higher Education Qualifications.
FMA	Foundation Modern Apprenticeship.
FMEA	Failure Modes and Effects Analysis.
FMS	Flexible Manufacturing System.
GCE	General Certificate of Education.
GDP	Gross Domestic Product.
HE	Higher Education.

HNC	Higher National Certificate.
HND	Higher National Diploma.
IB	International Baccalaureate.
ISO	International Organisation for Standardisation.
IT	Information Technology.
JIT	Just in Time.
LEA	Local Education Authority.
LSC	Learning and Skills Council.
MA	Modern Apprenticeship.
NC	National Certificate.
ND	National Diploma.
NQF	National Qualifications Framework.
NVQ	National Vocational Qualifications.
OECD	Organisation for Economic Co-operation and Development.
PDCA	Plan Do Check Act.
PEO	Performing engineering Operations.
PEST	Political, Economic, Social and Technological factors.
QAA	Quality Assurance Agency for Higher Education.
QCA	Qualifications and Curriculum Authority.
QFD	Quality Function Deployment.
QMS	Quality Management System.
SEMTA	Sector Skills Council for Science, Engineering and Manufacturing.
SME	Small and Medium Enterprises.
SMED	Single Minute Exchange of Dies.
SPC	Statistical Process Control.

SWOT	Strengths, Weaknesses, Opportunities and Threats.
TC	Technical Certificate.
TQM	Total Quality Management.
UK	United Kingdom.
UNCTAD	United Nations Conference on Trade and Development.
US	United States of America.
VAT	Value Added Tax.
WAG	Welsh Assembly Government.

CHAPTER 1

INTRODUCTION

The engineering industry within the UK is being defeated by competition from foreign companies and consequently national prosperity is being adversely affected. Although there is no single reason for the decline, it is clear that much of the problem originates from occupational deficiencies resulting from inadequate educational provision relating to poor curriculum design. This thesis proposes that synergy of traditional quality assurance techniques and curriculum design theory offers an opportunity to solve issues relating to poor educational provision. In particular, an innovative curriculum design method has been developed and subsequently applied in relation to a range of industrial organisations within the South Wales area.

This chapter discusses the background of the study and placement of the work in relation to other research is explored. The requirement for properly designed and deliverable curricula within the area of engineering education is established and some of the problems of using traditional techniques for curriculum design are identified and discussed. The output of this chapter is to establish that the problem confronting the providers of engineering education relates to quality assurance. Finally, the scope of the study and a guide to the remainder of the thesis is provided.

1.1 Background.

Since the start of the current decade, the manufacturing sector within the UK has experienced continued decline, Confederation of British Industry (CBI) (2008). A range of factors have contributed to this decline although a consensus appears to exist which identifies the more significant reasons as including: competition from the Far East, India, Brazil and Eastern Europe, the wider globalisation of the market place and the closing of the technological gap between developing and developed countries (Nellis and Figueira, n.d.). Despite contraction, the manufacturing sector (which includes the engineering sub-sector) continues to be a vital component of the United Kingdom's (UK) economy. Collins (2008) illustrates this continued importance by stating that manufacturing industry (which includes the engineering sub-sector) still accounts for approximately 15% of the UK Gross Domestic Product (GDP) and 55% of exports.

Engineering companies within the UK are long accustomed to change and the need to continually innovate and improve performance to remain competitive. Bhattacharrya (1998) recognises this by noting that the engineering sub-sector witnessed a move away from production maximisation in the 1970s to one of price driven supply in the 1980s and then to one of quality within the 1990s. More recently information gathering and handling, process control and management, research and development, design and market intelligence, all leading to customised added valued products has become the mantra for this and the next decade, Sector Skills Council for Science, Engineering and Manufacturing technologies (SEMTA) (2003). An essential part of this activity is the understanding that the skills base must be constantly re-evaluated and realigned if required, *The Working Document for the*

MANUFUTURE, European Union (EU) (2003). In extrapolating these findings, it is likely that in order to remain competitive many UK engineering companies will have to adapt and become more flexible. Localised production units, may for example, have to become more self-sufficient in order to minimise lead-time and maintain competitiveness in terms of cost and service provision. Conversely, centralised design and management facilities may have to reconsider their role with greater autonomy devolved to local production units. These studies indicate that a critical consideration in successfully managing these challenges will be ensuring that employees are provided with education containing an appropriate array of occupational, vocational and generic skills and curriculum design will be an essential component in this process.

Further studies have however identified that skill shortages and deficiencies are having a detrimental affect on the ability of engineering companies within the UK to compete and this evidence appears to demonstrate that existing curriculum design methods and outcomes are failing. Spinks, et al., (2006) for example, conclude from a survey of more than 400 engineering employers that problems exist in preparing students with adequate problem solving skills, the application of theory to real problems and inadequate mathematical ability. Charter (2002) also maintained that engineering companies have considered that students are not correctly prepared prior to taking up occupational and professional positions. In particular employers cited concerns about poor numeracy, literacy, basic technical knowledge and general life skills. These conclusions are supported within the UK Government's *Manufacturing Strategy* (2002) which stated that much of the productivity gap between the UK and its major competitor countries is considered to be as a result of poor education and the acquisition of skills. Taken together these studies essentially highlight issues relating to quality management exist in that current curriculum design and delivery methods appear unable to fully satisfy employer requirements.

Engineering education caters for a wide range of professions such as mechanical engineering, electrical engineering, electronics, automotive repair, marine engineering and aeronautical engineering. Reflecting this wide range of disciplines the number of individual occupations is large with organisations ranging in size from multinational companies to Small and Medium sized Enterprises (SMEs) - classified as companies employing less than 250 employees. Despite the diversity of employment within the engineering industry, the craft or technician apprenticeship has traditionally been the post-16 employment route into engineering. The UK Modern Apprenticeship (MA) framework comprises a National Vocational Qualification, Key Skills and a Technical Certificate (typically a National Certificate or the City and Guilds Certificate in Engineering). In the case of full-time students wishing to pursue a career in engineering a typical route is to study for a National Diploma (ND) or GCE A levels and then either, progress to Higher Education (HE) or gain employment.

It is significant that the various routes into the engineering profession have radically different philosophies and this clearly highlights the impact of educational ideology on curriculum design. Students in vocational education are exposed to a broad curriculum to develop general skills and technical knowledge designed to prepare them for a wide range of professional and occupational roles. Thus, within traditional vocational education instrumentalism is evident (Lewis, 1994). Wellington (1993) in comparing vocational education to general education (such as GCE A levels) concludes that general education is more progressive and liberal. Eisner and Vallance (1974) evaluate the orientation of curriculum philosophy and highlight its effect on decision making in terms of content, teaching and learning strategies, and assessment methods. These studies not only demonstrate linkage between ideology and curriculum design, but ideology and curriculum features and hence the selection and use of quality management techniques for effective curriculum design delivery and monitoring for this research.

The post-16 stage of education is critical in securing and developing people entering engineering professions and related occupations. During this stage of education regardless of the educational route taken, or their intended roles within an organisation, young people undertake a range of learning and developmental experiences which will determine the extent to which they are equipped with the required skills and knowledge to perform in the short, medium and long term. Specifically in relation to education of 16-18 year-olds, previous studies have again highlighted several related issues with regard to poor curriculum design and delivery. For example within Further Education (FE), *Engineering Education: the way forward* (NATHFE, 2003) identified inadequacies within craft-based training, vocational engineering courses and academic routes through from schools. This issue is compounded by insufficient recruitment onto FE engineering courses from schools (Confederation of British Industry cited in *Manufacturing News*, 2006).

Foskett and Hemsley-Brown (1997) discuss how engineering students within FE have complained that their education often fails to prepare them for clearly identifiable and specific trades or other job roles. Furthermore, they highlight concern that engineering as a profession lacks a clearly defined career path and has only a nebulous structure of ill-defined standards and roles which fails to build on the meritocracy of vocational skills or academic performance. It is arguable that engineering students compare the relative confusion within the engineering profession to the clarity often found in other professions, such as medicine for example. These issues, as well as other problems - notably the image of engineering, remuneration levels and the low number of females applying to enter engineering have resulted in recruitment difficulties and many employers continue to experience skill shortages in key areas (Hillage, et al., 2000). Thus, these studies further demonstrate recurrent issues relating to quality management exist in that existing curriculum design and educational provision does not fully satisfy student requirements.

In summary, it has been demonstrated that the engineering industry continues to be a vital component in the successful performance of the UK economy. However, to remain successful the engineering industry will need to be equipped with a manufacturing system which is attuned to the demands of its customers. A critical factor in satisfying customer demands and improving productivity levels will be the performance of the engineering workforce. Workers within engineering companies will need to be equipped with the vocational, technical, generic and managerial skills required. Despite identifying the importance of this issue, evidence suggests that employers are encountering deficiencies in skills among employees and this is particularly significant with regard to the recruitment of 16-18 year olds. A recurrent theme of the studies considered is therefore that existing curriculum design methods are failing. In particular, utilisation of existing curriculum design methods has resulted in poorly designed educational courses which are failing to satisfy employers and students alike. An hypothesis is therefore proposed that within the curriculum design process the issue confronting the providers of education is one of quality management in that providers must know how to: (1) anticipate and understand customer requirements and (2) translate and satisfy these customer requirements into a deliverable curriculum package.

1.2 Traditional approaches to curriculum design.

Approaches to develop an understanding of stakeholder and customer requirements within the area of educational curriculum design have centred on the use of curriculum theorising and models. Marsh (2004) categorises curriculum theorising as prescriptive theorising, descriptive theorising or critical-exploratory theorising and each demonstrates a different emphasis.

Prescriptive theorising

Prescriptive theorising involves an attempt to create models or frameworks for curriculum construction. Tyler (1971) proposes a four-stage approach as follows:

- Establish the curriculum aim and objectives.
- Determine which learning experiences meet the aims and objectives.
- Determine how these learning experiences can be organised into a curriculum programme.
- Determine how the programme can be evaluated.

This highlights prescriptive theorising as attempting to specify behaviourist objectives to what should learnt and to define what educational experiences are most likely to attain them. This approach to developing a curriculum has found resonance in vocational education where the importance of learning specific skills and competencies is highlighted. However, it is arguable that a prescriptive approach to curriculum design contains inadequate consideration of cognitive and humanist learning theory.

Descriptive theorising

Descriptive theorists such as Walker (cited in Marsh, 2004) attempt to establish how curriculum planning actually (rather than should) take place. Walker (1971) for example, proposed a three-stage model involving the establishment of a platform, deliberation and design. Walker argues that actual curriculum design is complex and cannot be described in a prescriptive manner. Walker therefore identifies that curriculum planning, although influenced by fundamentally held beliefs and values, is achieved when sufficient consensus emerges on what can practically be implemented. This demonstrates that descriptive theorising has the advantage of recognising the importance of culture and social issues in curriculum design. Conversely, it is arguable that descriptive theorising (in comparison to the prescriptive approach) prevents ease of use in application.

Critical-exploratory theorising

Critical-exploratory theorists attempt to identify and correct deficiencies in curriculum planning practice. Thus, critical-exploratory theorists are concerned with either the connection of education to social and cultural order or that curriculum design should be used to enhance the personal learning experience of the student. The critical-exploratory approach therefore places emphasis on the individual learner and the ability of the curriculum to provide opportunities for the attainment of higher levels of consciousness and fulfilment. This approach to curriculum design is more in accord with the ideology of liberal humanism within education in reflection of concerns expressed by students. Thus, it would appear to offer opportunities for increased activity and co-operation at higher levels of learning.

1.3 Problem discussion.

Regardless of the individual approach adopted curriculum design methods remain essentially methodical in nature. This approach to curriculum design is clearly analogous to many established Total Quality Management (TQM) continuous improvement methods such as Plan-Do-Check-Act (PDCA), Define- Measure-Analyse-Improve-Control (DMAIC) and Quality Management Systems (QMS) such ISO9000. In terms of understanding customer requirements, existing curriculum design methods clearly recognise the requirement to identify and understand the needs of the customers. However, it is unclear how this can be practically and effectively completed.

It is hypothesized in this thesis that an opportunity exists to synthesize elements of curriculum design and quality management to produce an alternative method of curriculum design which contains sufficient flexibility and sophistication to overcome deficiencies by:

- Recognising the diversity of service provision required.
- Accurately defining customer requirements.

- Translating customer requirements into meaningful deliverables.
- Recognising the importance of a methodical yet flexible approach to continuous improvement.
- Being complementary to the learning perspective of the students.

1.4 Background of the author.

The author of this thesis is employed as a lecturer in mechanical engineering at Coleg Sir Gâr. Prior to working at the college the author gained many years experience as a Quality Assurance Manager within large multi-national manufacturing organisations, including Sony (UK) Ltd. In terms of early development the author undertook a recognised apprenticeship including the completion of related academic and vocational studies. These professional and personal experiences are directly related to this thesis. In particular, there is a desire to improve the effectiveness of engineering education for the benefit of engineering companies and the students undertaking that education.

1.5 Scope.

The premise taken in this thesis is that the issue confronting the providers of education is one of quality management. No attempt is made to supplement the pedagogy of teaching and learning. However, in recognition of the need to develop a curriculum proposal in a complementary and sensitive manner to the requirements of engineering students, learning theory and curriculum design centred on the use of curriculum theorising and models is investigated and conclusions drawn. Implementation of the final curriculum proposal is with respect to the education of

16-18 year olds and a range of engineering companies within the South Wales region.

1.6 A guide to the thesis.

Chapter 1 provides a background to the study and indentifies the problem under consideration. The recurrent theme of inadequacy in quality management within current curriculum design methods is demonstrated and a solution hypothesised. The scope of the thesis is also defined.

Chapter 2 is used to develop the context of the study and review established methods for quality assurance both in commercial organisations and within education. As a result of this literature review the specific aims and objectives (identified as a,b,c,d,e,f and g) of the thesis are subsequently established. These provide a justification for the curriculum design method itself, which is subsequently explained in chapter 3.

The remainder of the thesis is used to apply the devised curriculum design method and establish the curriculum proposal in relation to a selected range of engineering companies within the South Wales region. This limited application is justified due to the nature of the work of the writer as a tutor within Coleg Sir Gâr. Also, by concentrating on the requirements of these companies, it was possible to evaluate the effectiveness of the curriculum design method and produce a specific output relevant to the author and his employer. In implementing the curriculum design method it was necessary to initially establish the drivers of change which determine the educational requirements of engineering companies (ref objective a). Chapter 4 is therefore used to identify the salient drivers of change impacting on engineering industry within the wider UK economy (particular consideration is given to economic, technological and occupational factors).

Recognising the need to develop the final curriculum proposal in a complementary and sensitive manner to the requirements of engineering students chapter 5 explores learning theory and related curriculum planning issues as well as matters relating to learning and assessment methods (ref objective d). To allow for an evaluation of the effectiveness of existing engineering educational provision (in comparison against the final curriculum proposal) chapter 5 is also used to investigate a range of awards (within the 16-18 year age group in Wales) as well as the existing Modern Apprenticeship (MA) framework within Wales (ref objectives f and g).

Using the output of chapter 4 a suitable profile of technical, occupational, and generic skills is established in chapter 6 (ref objective b). The relative importance of each of these competencies was then tested and confirmed through research conducted with a range of engineering employers relevant to Coleg Sir Gâr (ref objective c) - the results of which are included in the final curriculum proposal.

Although the requirements of the engineering companies was taken to be of primary importance, the curriculum requirements the students at Coleg Sir Gâr was also recognised and subsequently investigated. Specifically, preferred learning styles, preferred methods of learning, preferred methods of assessment and the acquisition of specific and generic competencies were considered - the results of which are provided in chapter 7 (objective e).

Chapter 8 is where synthesis of the data is achieved. The output of chapter 8 is therefore the construction of a curriculum proposal which is an accurate translation of the customer requirements into deliverable curriculum characteristics. Chapter 9 is used for discussion of results, conclusions and recommendations for further work. The entire process in flow-chart form is illustrated in figure 1.1

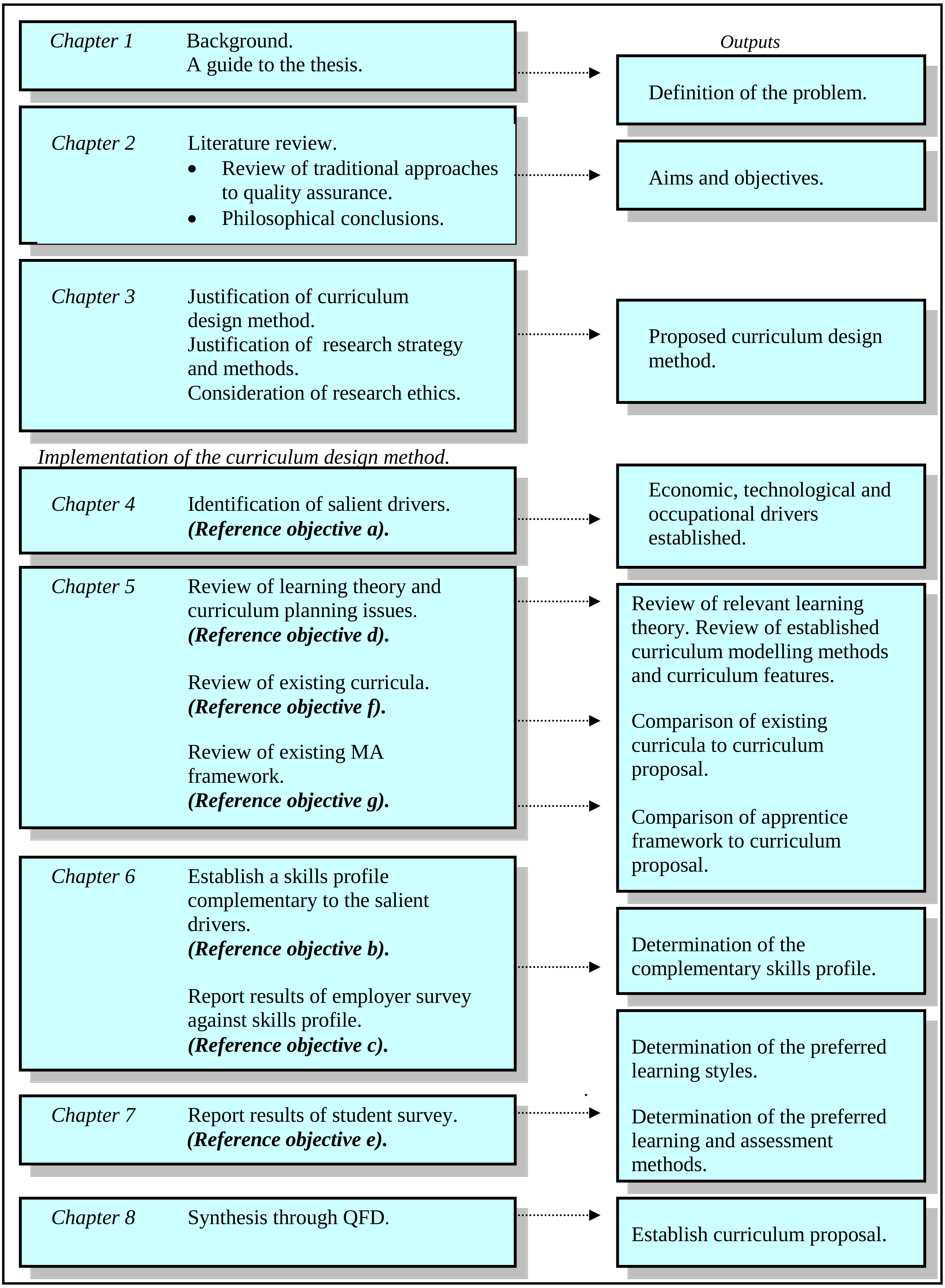

Figure 1.1 Flow chart illustrating the approach taken.

CHAPTER 2

LITERATURE REVIEW

This chapter is used to develop the context of the study and review established curriculum design methods based on the use of curriculum theorising and models. The definition of quality within an educational context is explored and factors affecting curriculum design identified. Subsequently, existing curriculum models are reviewed and then quality assurance techniques used in commercial organisations and education are compared and contrasted with conclusions drawn. Finally, possible synergies between TQM and traditional curriculum design methods are established and a philosophical justification for the tentative design of a new curriculum design method is offered. Specific aims and objectives of the thesis are consequently established.

2.1 Definition of quality.

Before investigating traditional approaches to quality assurance it is worth defining what is meant by the term “quality” and a number of notable definitions have been offered.

Crosby (1984, p.59) defines quality as “conformance to requirements” . This definition has the advantage of providing a clear manner in which to quantify explicit customer requirements but it is likely that some organisations are unable to fully appreciate implicit service requirements and product characteristics. The International Standards Organisation (ISO) attempts to overcome this issue by defining quality as “the totality of features and characteristics of a product or service that bear on its ability to satisfy stated and implied needs”, (cited in Bendell, 1993). Similarly, Feigenbaum (1991, p.7) defined quality as “the total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectations of the customer”. Defining exactly what is meant by the term quality remains somewhat subjective and these definitions can be perceived as complicated. In that respect a simple and effective definition of quality is offered as being “fitness for purpose” (Juran, 1998, p.2.2). This definition has the advantages of providing a clear customer focus and applicability to service functions in meeting the agreed requirements of the customer. This definition of quality also allows for accommodation of the fact that quality will be perceived differently by each stakeholder. Within an educational context, students for example, will see quality in terms of learning provision but employers may perceive quality in terms of skills gained. This situation has implications in terms of curriculum design where competing demands may be evident.

Despite diversity in its definition, it should generally be accepted that quality (in a business sense) refers to the degree to which a product or service meets customer expectations. Furthermore, since institutional references to quality within education are often customer-centred with explicit reference to customer satisfaction or a stated level of entitled provision, it is arguable that some established definitions of quality are more applicable than others. In that sense it is proposed that the most appropriate definition is offered by Juran. Significantly, this definition of quality is complementary to the requirements for a curriculum design method as developed in the problem statement (see chapter 1.3). However, the question that remains unanswered is how can the process of curriculum design best satisfy these requirements?

2.2 Factors affecting curriculum design.

Before attempting to investigate curriculum modelling and design it is beneficial to clearly define curriculum. Jenkins and Shipman (1976) define curriculum at award level which is taught and learned within a school or other institution. Armitage, et al., (2002) propose a similar definition but observe that in practice teachers and tutors are disposed to consider the curriculum to be whatever is being taught at the time. Other authors see the curriculum in broader terms and consider institutional, social, political and economic factors in order to place it into context. Kerr (cited in Smith 2000, p.1) defines curriculum as “all the learning, which is planned and guided by the school, whether it is carried on in groups or individually, inside or outside the school". Nicholls and Nicholls (1978, p.10) concur by proposing that the curriculum is "all the activities planned by teachers for pupils". Despite diversity in the definition there is broad agreement that a curriculum involves the interaction of content, teaching methods and purpose (Taylor and Richards, 1987).

Political, Social, Economic and Technological (PEST) factors all influence the design of curricula. Furthermore, the implementation of curricula is affected by the interpretation of educational establishments, tutors and students. Marsh (2004) provides evidence for this by considering that political influences on the curriculum are particularly significant with successive UK governments (both Conservative and Labour) with differing educational ideologies, having attempted to define the purpose, scope and content of curricula within both pre and post-compulsory education. Frankel and Reeves (1996) also acknowledge that changes in curricula reflect upon differing political ideologies and are often related to a desire to impact upon socio-political or economic change.

Viewed from an industrial-training educational perspective and in relation to post-compulsory education the more significant pieces of legislation/reports within the last twenty years include:

- *The Education Reform Act 1988* which allowed FE Colleges to gain some limited independence while still remaining under the control of the Local Education Authority (LEA).

- *The Higher and Further Education Act 1992* which allowed for the incorporation of FE colleges and the break away from LEA control. FE colleges were given the power to manage their own finances and recruitment under the control of new funding councils.

- *The Kennedy Report – Widening Participation in Further Education "Learning Works" 1997 and the Dearing Report – National Committee of Inquiry into Higher Education 1997* . Both had a significant impact on the direction and focus of FE institutions in terms of defining their role in the revitalisation of communities.

- *The Tomlinson Report 2004* which focused on the 14-19 agenda.

- Leitch (2006) *Prosperity for all in the global economy – world class skills* established range of recommendations relating to improving work based skills.

Considering the results from these items of legislation/reports it appears that a consensus has arisen which generally identifies post-compulsory education as being involved in attempts to raise economic performance and prosperity. This is characterised by technical and vocational education in which there has been increased emphasis on the use of competency-based qualifications. These involve the use of criteria-based assessment methods to assess knowledge, modular forms of delivery and the use of quality control procedures and systems used to monitor performance. Specifically within Wales, The Welsh Assembly

Government (WAG) has also driven political change through curriculum design and again in relation to the post-compulsory educational sector significant recent curriculum developments in Wales have included:

- The Welsh Assembly Government's *The Learning Country* 2001 which reflects the ethos of widening participation.

- The Welsh Assembly Government's *Learning Pathways 14-19* 2004 which requires FE colleges to expand provision and contribute to a widening of choice for 14-16 year olds.

- *The Webb Report* 2007 which is a comprehensive policy review of the purpose and scope of further education within Wales.

These documents demonstrate a broader political philosophy in Wales. Curriculum change is concerned with providing the skills required by the economy but also widening participation and tackling social exclusion by raising standards and improving performance through partnership and collaboration and ensuring effective governance and management. Significant strategies developed to ensure improvement in these areas include the 14-19 Learning Pathways, e-Learning, Key/Basic Skills, Welsh medium and bilingual provision, Community Learning Networks, development of work-related learning, stated entitlements to support young people in Wales, sustainable development and global citizenship, polices for social inclusion and equal opportunities and the provision of careers advice.

In summary, curriculum design is complicated by a range of stakeholder demands, wider economic and social considerations as well as the requirements of the direct customers themselves (namely the students and employers). Evidence has been provided for the increased importance within technical and vocational education of instrumentalism and a competency-based approach where the delivery of a curriculum is associated with the development of the workforce. Notably, this view is in accordance with the premise of this thesis which views a highly educated and well trained workforce as essential in meeting growing international competition (see chapter 1.1).

2.2.1 Curriculum planning in technical and vocational education.

The United Nations Educational, Scientific and Cultural Organisation (cited in Tappin 2002, p.3) defines technical and vocational education as "all forms and levels of the educational process involving, in addition to general knowledge, the study of technologies and related sciences, the acquisition of practical skills, know-how, attitudes and understanding relating to occupations in the various sectors of economic and social life". This definition highlights that technical and vocational education supplements other educational provision with an understanding that skills development is seen as important. This definition of technical and vocational education also blurs the distinction between education and training. However, education can be said to involve experiences involving the development of the individual which are deeper and broader than training, which is more concerned with the acquisition of narrower skills (Rogers, 2002).

The United Nations Educational, Scientific and Cultural Organisation’s definition appears to be consistent with a prescriptive approach to curriculum design (with its focus on behavioural targets). Kemp (1999) in considering curriculum planning within technical and vocational education highlights market forces and employer requirements as significant drivers which have lead to competency-based learning incorporating the use of learning outcomes. Identifying learning outcomes as - what a learner knows (Allen, cited in Kemp 1999) argues that this emphasises learning as being able to perform tasks in an observable manner. Consequently, it is recommended that learning outcomes be integrated as either personal transferable outcomes, generic academic outcomes or subject specific outcomes. It is possible to conclude that in terms of skill acquisition these definitions relate to the commonly utilised terms of transferable skills, key skills and job specific skills. However, what is often unclear in practice is the exact relationship between outcomes, and surely there must always be a principled and theoretical justification for the selection and interrelationship of learning features and outcomes within a curriculum proposal.

It is also reasonable to assume that not all instructional objectives need to be defined in restrictive behavioural terms. Bloom (1960) in establishing the taxonomy of educational objectives provided a basis for classifying learning into domains and thus highlights learning outcomes should be hierarchical and concerned with different forms of learning (see chapter 5.1.1). Thus, a conflict can be noted with respect to how competency-based learning would best develop individuals in broader cognitive and affective terms. Hyland (1994) supports this view by asserting that competency-based qualifications, such as National Vocational Qualifications, are conceptually confused and based on discredited learning theory. Bull (1985) provides further criticism in stating that competency-based education is focused too greatly on the needs of commerce and industry rather than the needs of the individual and society generally. Bull further considers that performing to pre-determined national standards will result in pre-conditioned responses, which do not allow for student-centred learning activities. Limited attempts to address these philosophical criticisms have been applied. This is illustrated by the amendment of NVQ standards within the UK to include the requirements of underpinning knowledge and understanding. Furthermore, at higher levels of NVQ attainment the need for the candidate to be creative, self-motivated and show initiative has been introduced. Candidates at higher levels are also required to produce a commentary which is essentially a critical review (reflection) of their performance. Nevertheless, it is clear that the increased importance of instrumentalism in education has lead to the widespread use of prescriptive theorising and in particular the use of Tyler's model for curriculum design.

2.2.2 Curriculum models.

Tyler (1971) proposes a four-stage linear process as follows:

- Establish the curriculum aim and objectives.
- Determine which learning experiences meet the aims and objectives.
- Determine how these learning experiences can be organised into a curriculum.
- Determine how the programme can be evaluated.

As previously stated this approach to developing a curriculum has found resonance in vocational education where the importance of learning specific skills and competencies is highlighted and thus the practicality of the curriculum model is appreciated. As an objectives-based model it does therefore offer the advantages of having a consistent philosophical outlook (when seeing a curriculum in terms of economic performance), simplicity in use and is complementary to the managerialist drive for quality (often defined in commercial terms). Issues to be resolved are its over-emphasis on behavioural outcomes and the largely passive role of students. Bridges (1986) supports this view and argues that learning should be seen as a continuous process whereby students learn how to learn rather than have some pre-determined end point when an outcome is met. Taylor and Richards (1995) also criticise linear models (such as Tyler's model) in that to define a curriculum as a series of separate stages is unrealistic as in practice some feedback from an output will affect the input stages. This is an important consideration in relation to this thesis since the dynamic nature of customer requirements has already been acknowledged.

Reflecting on Tyler's model for curriculum design it has been seen to offer the advantage of utilising a systematic model containing clearly stated inputs and outputs. However, it is unlikely that many of the wider personal, social, ethical and moral issues centred on the student are fully included. Refining of the model to include a mechanism to define learning in relation to the learner would increase its effectiveness and be more progressive. Furthermore, since the demands of engineering employers (and students) are dynamic a mechanism for continuously reviewing the effectiveness of the curriculum should be established. Thus, a system which allows for the determination of learning outcomes (as established and owned by the students) would appear to be beneficial in comparison to a system which enforces predetermined learning objectives.

Alternatives to the linear model have been developed. Lawton (1983) proposed an approach to curriculum planning which views education and learning as a process but extended to include the passing of cultural values down through the generations. Thus, this model is designed to allow for cultural values to be transmitted by the teacher, received by the learner, reflected upon by the learner and if accepted, integrated by the learner. Therefore, the model does recognise wider philosophical and sociological aspects to curriculum design and is consistent with a descriptive philosophy to curriculum design. In relation to the instrumentalist perspective of this thesis it would however appear to be of limited use due to the absence of practical mechanisms for implementation.

Wheeler (1967) also proposes a process model which emphasises curriculum design as an ongoing process of establishing the learning objectives, deciding upon the curriculum content, the method of delivery and the evaluation of performance. This approach offers the advantage of recognising the dynamic nature of customer requirements and has feedback from the output of the model. It is however again unclear how practical interpretation of customer requirements could be translated into curriculum features. Specifically in terms of FE the Further Education Development Unit (FEDU) (1988) proposed a curriculum development model which takes into account continuous evaluation and review. In comparison to the traditional linear model of curriculum design the FEDU model replaces curriculum “objectives” by a “needs analysis”. This is consistent with the premise of this thesis in acknowledging that curriculum design should not only consider outcomes in terms of specific behavioural objectives but that factors such as learner needs must also be factored into the design of a curriculum proposal. Complementary to this philosophy must be the subsequent identification of suitable learning methods and materials as well assessment mechanisms.

A philosophical departure from the competency-based model is the development of the International Baccalaureate (IB). Sobulis (2005, p.2) states that the primary goal of this form of education is to “develop critical thinkers, since the moral, social, and political issues of the world often engage emotions, and passions as well as intellect”. Bagnall (cited in Sobulis, 2005) however placed criticism on this form of education for being inappropriate to current economic conditions by failing to improve the employment prospects of students. This argument is however counteracted by proponents of the IB, such as Green (cited in Sobulis, 2005) who states that students are in fact particularly well prepared for the job market through the development of transferable skills inherent in this liberal form of education. Seltzer and Bentley (cited in Standish, 2001) concur by arguing that educational establishments must promote forms of learning that develop creative abilities. Standish (2001) in considering this matter further, questions how successfully these transferable skills (now associated with the teaching and assessment of Key Skills within many schools and colleges) are being delivered.

The development of the International Baccalaureate curriculum illustrates essential differences between a progressive and an instrumentalist approach to curriculum design. Wellington (1993) offers an explanation of two paradigms which differentiate the provision of technical and vocation education from general education. Wellington observing that technical education being technocratic, concerned with economic regeneration and meritocratic. General education being considered as more liberal, democratic and egalitarian.

2.2.3 Review of curriculum design.

Despite differing interpretations of quality the established approach to curriculum design is based upon either theorised prescriptive, descriptive or critical-exploratory models. In practice the selection of a particular approach to curriculum design is heavily dependent on the political ideology of the author and as well wider socio-economic factors. As a result of differing philosophical perspectives the application of curriculum design is complex and multi-faceted. In relation to post-compulsory education a consensus has developed which views vocational education as being involved in attempts to raise industrial and commercial performance and this has lead to the development of a predominantly competency-based approach to learning. This philosophical perspective on the purpose of learning is in accord with a prescriptive approach to curriculum design as typified by the Tyler's four-stage approach to curriculum design. In practice the competency-based approach to curriculum planning leads to the establishment of specified learning outcomes and reflects a desire to ensure educational outputs are measurable. By specifying learning outcomes and competencies, a market-lead employment-based context of educational is efficiently accommodated. Further, the use of a prescriptive approach to curriculum design has found resonance within vocational education and advantages identified include its simple and rational approach - which is complementary to the command and control management structure found within many educational establishments.

Curriculum planning issues relating to the use of specific behavioural outcomes within technical and vocational education have however been highlighted and an alternative and more progressive approach discussed. Particular concern has been expressed about the possibility that curriculum design using a prescriptive approach can lack in social relevance and this may present problems to the learner and prevent flexibility in delivery. Similarly, by assuming that objectively observing a series changes in behaviour will provide evidence of learning can potentially result in educators losing sight of the overall learning goals. Hence, a student-centred approach is desirable and it is reasonable to hypothesize that the development of the new curriculum design method will need to incorporate elements of both the competency-based and progressive approaches to curriculum design. As highlighted in chapter 1.3 it is also possible to hypothesize that to provide this flexibility and sophistication the synergy of appropriate quality management techniques and curriculum design can be used. These quality management techniques are discussed in chapter 2.3 as follows.

2.3 Traditional approaches to quality assurance.

The evolution of Total Quality Management (TQM) can be traced from fundamental quality control and quality assurance techniques. Feigenbaum (1991) developed the concept of Total Quality Control and highlights the integration of quality development, quality maintenance, and quality improvement. Oakland (1993, p.42) proposed that TQM was the company-wide integration of “culture, communication and commitment" (termed soft outcomes) and "systems, tools and teams" (termed hard outcomes). ISO 8402:1994 defines TQM as a management approach of an organisation centred on quality, based on the participation of all its members and aiming at long-term success.

These definitions although significant do not readily allow for the practicalities of how TQM can be effectively used. Kanji and Asher (1996, p.1) provide guidance in stating that TQM can be considered to encompass the core principles of "delighting the customer, management by fact, people-based management and continuous improvement". Schonberger (1982, p.2) considers TQM as a "collection of procedures and techniques". These clarifications of the guiding principles of TQM are helpful in identifying that fundamentally TQM is an amalgamation of management values and systems, analytical tools and techniques and customer focus. The possible synergy of curriculum planning and quality management has already been identified as a means of improving customer satisfaction within education but in defining the diverse nature of TQM it is clear further consideration is required. For the purpose of this thesis the TQM elements of management values and systems, analytical tools and techniques and customer focus will provide appropriate scope and each of these elements is now considered in turn.

2.3.1 TQM - management values and systems.

It has been demonstrated that the practical attainment of TQM can be approached in a number of different ways. Despite this diversity, efforts can be said to centre on a process control approach (typically associated with continuous improvement through the reduction of variability) or a management systems approach (such as ISO9000).

This may be considered a simplistic view since the application of TQM often includes the integration of management systems and process control. This development is evident in ISO 9000:2000 which requires registered companies to adopt a process approach to developing, implementing and improving the effectiveness of the quality management system. Henderson and Evans (2000) also discuss the integration of the management systems and process control approaches in describing how the Six Sigma improvement methodology is used widely in management and service functions. Nevertheless, in terms of this thesis, by considering the practical implementation of TQM as being either concerned with a process control approach or a management systems approach, a suitable concept for further investigation and comparison has been established.

2.3.1.1 The process control approach.

Conceptualizing the provision of a service or a product as a process is a common element in the management of quality (Schmidt and Launsby, 1998). Visualisation of production processes, organisational flow or service provision in this manner does appear to have a number of clear advantages. Firstly, it identifies that processes inherently involve the orderly transformation of process inputs to outputs. Secondly, processes can be seen to contain inherent variability and consequently quality becomes measurable and can be improved by identifying and reducing the causes of variation. Thirdly, within the concept of process control is the provision of feedback and thus linkage between the process and customer satisfaction is established. Deming (1982) provides much of the early work in developing a process-based philosophy for customer satisfaction. Deming (as cited in Schmit and Launsby 1998, p 1-13) demonstrates the importance of a process perspective to improving quality by stating that “quality does not come from inspection, but from improvements on the process”. Central to continuous process improvement must be an understanding of the process and its variation (Deming, 1986). Deming (cited in Walton, 1988) further recommended the use of PDCA as a means of problem solving and satisfying the quality requirements of the customer.

PDCA is an iterative four-step problem-solving method. Galen, et al., (2000) view PDCA as the scientific method where:

- Objectives are firstly set or solutions hypothesized (Plan).
- Action implemented (Do).
- Results gathered and compared against the original objectives (Check).
- Action taken to provide improvement before the next iteration (Act).

Thus, PDCA appears to be analogous with Tyler’s prescriptive philosophy of curriculum planning in that both use a systematic approach to:

- Establish the curriculum aims and objectives (Plan - objectives set).
- Determine the learning experiences and how they can be organised into a curriculum (Do - action is implemented).
- Determine how the programme can be evaluated (Check - results gathered and compared against the original objectives).
- Corrective action to enhance the provision is taken (Act - provide improvement before the next iteration).

With regard to the delivery of education several studies have highlighted attempts to utilise PDCA. (The American Society for Quality, n.d.) for example reported the successful use of PDCA in New York State schools for investigating needs, curriculum design and the provision of student services. This demonstrated an attempt to address the "Plan" stage of the cycle. However, as only student requirements were considered, this study can be criticized for ignoring wider stakeholders (including employers) and this is an important omission. Draugalis and Slack (1999) discuss of how the proactive and continuous use of PDCA in the provision of Higher Education provided substantial cumulative benefits. This study looked to address the "Do" stage of the PDCA cycle but was limited in scope (being essentially concerned with integration of assignment work to reduce student workload). It does however illustrate that wider curriculum issues relating to assessment, learning methods and course management need to be considered at this point within the PDCA cycle. Brawner, et al., (1997) highlight issues relating to qualitative evaluation and control management systems and specifically proposed a 10-point system of evaluation and control. This review is useful in demonstrating the complexity of control required in education and indicates that a predominantly qualitative control system is likely to remain appropriate for most educational institutions.

Successful use of PDCA in educational settings demonstrates its applicability for continuous improvement. Continual improvement in an educational sense includes changing learning processes and the use of alternative learning theories, the deployment of new technologies, utilising differing learning and assessment methods and the evaluation of differing learning styles. PDCA is conceptually simple and when considered as a scientific method has added credibility because of its ability to provide feedback and therefore would appear to offer flexibility in use. Processes can for example be defined as manufacturing processes or management processes or indeed educational processes and each would have implications in terms of subsidiary selection and use of specific quality management tools for data gathering and analysis (see chapter 2.3.1.2). Implicit in this statement is that statistical or analytical methods are often preferred and this would appear to present problems in implementation within an educational context. It is not difficult, for example, to foresee the use Statistical Process Control (SPC) based on attributes for educational processes but it is debatable if there is sufficient knowledge and acceptance of this technique among staff in the education sector.

In conclusion, previous studies have demonstrated that PDCA is capable of producing qualitative curriculum characteristics and is dynamic enough to reflect diversity in provision and changing demands. The studies do not adequately explain how to accurately determine learning aims and objectives (the customer requirements) or how they can be translated into curriculum features. Further consideration would also appear to be required in respect of how to effectively amalgamate the use of PDCA and traditional educational management structures and practices.

Alternative concepts to the use of PDCA have been proposed as a means defining and controlling and improving processes.

DMAIC

The Six Sigma philosophy employs a modified version of the PDCA cycle, which is termed Define, Measure, Analyse, Improve and Control (DMAIC) (Schmit and Launsby, 1998). This methodology is an attempt to develop a more analytical, data-driven approach to problem solving. Comparing methodologies DMAIC places greater emphasis than PDCA on determining a numerical target value and stresses that the output from a process is a function of its inputs. Consequently, use of techniques such as Design of Experiments (DoE) for process optimization and Statistical Process Control are encouraged. The reduction of process variability is fundamental to the philosophy of Six Sigma and is therefore aligned with the Taguchi loss function in that both recognise that a reduction in variability leads to a decrease in loss and a subsequent increase in quality. Taguchi (cited in Yang and El-Haik, 2003) however places greater emphasis on routine optimisation of products and processes prior to manufacture to ensure products are robust against process variability. Possible use of a loss function in an educational context would appear to offer advantages. For example. loss in personal, social and economic terms clearly results from poorly designed and implemented curricula. Further, Taguchi's emphasis on design could supplement existing curriculum design practices in order to establish target values for provision standards. However, the potential use of DMAIC (and allied concepts) in education may again present difficulties due to insufficient knowledge and acceptance of these techniques among curriculum planners in the education sector.

Hoshin Kanri

Adaptation of PDCA is evident in the development of Hoshin Kanri. Akao (2004) demonstrates that Hoshin Kanri systematically seeks to create organisational goals, identify subsequent control points and link daily control activities to company strategy. Akao (2004) also recognizes Hoshin Kanri as essentially driven from a strategic planning level. Since within an educational context management is often concerned with longer-term strategic goals, opportunities for the exploitation of Hoshin Kanri appear to exist. However, this may present inherent cultural problems when applied to an educational setting in which detailed planning and rigid implementation can be counter to liberal traditions and where alterations in performance are often driven from below and from outside the organisation. Further, as Hoshin Kanri is often concerned with achieving objectives over the longer-term it is debatable if Hoshin Kanri is as dynamic as PDCA in reflecting changing student and employer requirements.

Juran (1988, p.3) also identified the critical importance of quality in defining the management process as "establishing specific goals to be reached, establish plans for reaching the goals, assign clear responsibility for meeting the goals and base the rewards on the results achieved". Significantly, Juran identified the concept of internal and external customers and this would offer opportunities in overcoming issues relating to the complexity of interaction between direct and support functions within education and the satisfaction of all stakeholder needs.

2.3.1.2 The management systems approach.

Despite diversity in the techniques available to understand and satisfy customer requirements many educators persist in using a pragmatic approach. This is a more systematic approach to understanding customer requirements. The development of quality within the area of educational provision is accurately reflected in the management of quality taken by many educational providers. This is often based on a Quality Management Systems such ISO9000, The European Foundation for Quality Management (EFQM) Excellence Model or some other institutional administrative/ bureaucratic system of control.

Since a standards-correction approach to quality (often contained within cycles of audit and other management control methods) is a traditional approach within education it is not difficult to foresee the familiarity a management systems approach would offer. As previously identified educational institutions also have to recognise the complexity of provision to various stakeholders (employers, students, governmental funding agencies, external awarding bodies etc) each having different but valid expectations in terms of quality. This presents a problem within an educational context in defining quality differently for each stakeholder (often with characteristics which are intangible and difficult to quantify). Using a management systems approach to quality does offer an opportunity to organically develop a multi-faceted system which can accommodate this diversity. A management systems approach to quality is also complementary to the hierarchical systems of management in education (in which a matrix system is often preferred) and within which there is complex delegation and decision making responsibilities.

The International Organisation for Standardization maintains ISO9000 - the internationally recognized standard for quality management systems. ISO9000 comprises a number of standards that specify the requirements for the documentation, implementation and maintenance of a quality system. A similar, but less prescriptive approach is offered by the European Foundation for Quality Management Business Excellence Model. Despite an emphasis on documented management control ISO9000 also promotes the adoption of a process approach to developing, implementing and improving the effectiveness of the QMS through considering inputs to the system, processing of those inputs and the generation of outputs. Therefore four key areas of importance are identified as follows:

- Establish the customer requirements and the processes necessary to delivery them.
- Implement the process.
- Monitor the process against the customer requirements.
- Take action to improve the process.

The EFQM model also provides for a systematic (but less prescriptive) approach to improvement in performance by aiding organisations to develop a measurable strategy for future development and to aid in the identification, support and improvement of key relationships within their process.

The use of Quality Management Systems to ensure quality has however received criticism. Clifford (1995) for example, states that commensurate to the time and expense required to implement ISO9000 there is inadequate return on improved performance and that continuous improvement can be stifled by overly bureaucratic procedures. Dick (2000) in conducting a literature review saw no proven link between quality certification (ISO9000) and improved customer satisfaction. Seddon (2000) specifically criticises ISO9000's applicability to service organisations and its over-emphasis on management control. Likewise, the EFQM model has attracted criticism for a lack of content and guidance in providing for practical solutions to problems (Seddon, 2006).

2.3.2 TQM - analytical tools and techniques.

Oakland (1993) categorises TQM tools and techniques as concerned with either the measurement of quality, quality improvement or process improvement. In terms of management values and systems the methodologies in focus within this thesis are process management and systems management (as highlighted in chapter 2.3.1.1). Within this definition the selection and use of quality management tools for data gathering and analysis has already been highlighted as an important consideration. In the context of this thesis it is envisaged that opportunities for the use of specific tools and techniques exist for the determination of customer requirements and the translation of customer requirements into meaningful deliverables. Within this constraint, basic tools and techniques for quality improvement (such as histograms, scatter diagrams, histograms, Pareto charts, cause and effect diagrams and control charts) are not considered. Investigation is limited to tools and techniques with a greater customer focus and these techniques are discussed further in chapter 2.3.3 as follows.

2.3.3 TQM - customer focus.

Fundamental to the philosophy of TQM is the requirement for customer-focused continuous improvement. The alignment of customer requirements to internal processes is typically through the use of a number of different methods for investigating, translating and satisfying customer requirements. Talluri (2000) refers to efforts at a strategic business level to address customer satisfaction and highlights the use of benchmarking and Business Process Reengineering (BPR). Both benchmarking and BPR are valid techniques to enhance customer satisfaction but it is not the purpose of this thesis to radically reconfigure delivery or compare performance. The target is to optimize the design and delivery of the curriculum and thus it is considered that techniques such as Quality Function Deployment (QFD) and Failure Modes and Effects Analysis (FMEA) are more applicable and will offer adequate scope for this thesis.

2.3.3.1 Quality Function Deployment.

Akao (1990, p.4) defines the use of QFD as providing "positive quality". It is notable that this definition of quality provides a practical mechanism for analyzing and understanding the quality requirements of the customer. Akao (1990, p.5) illustrates this concept by defining QFD "as connecting the consumers demands to quality characteristics and developing a design quality for the finished product by systematically deploying the relationship between the demands and the characteristics, starting with the quality of each functional component and extending the deployment to the quality of each part and process". The final output of the QFD is a set of targets for each technical requirement which must be satisfied by the new product or service under consideration. Specification values are subsequently established for the design measures identified. Often it is the setting of these values that will establish and drive the improvement plan. Specification values are set by considering customer requirements, current service provision, benchmarking data and trade-off considerations.

Within the basic approach to the use of QFD a number of alternative models have been developed (ReVele, et al., 1998). The four-phase approach is among the most common and uses a series of matrices. Using this method it is possible to initially translate customer requirements into a product characteristics matrix. The product characteristics matrix is in turn translated to form the matrix for part characteristics. Subsequently, the parts matrix is translated into a process matrix and finally the process matrix is translated to form a production control matrix. Lowe and Ridgeway (n.d.) highlight the matrix of matrices method which allows for specific matrices to be constructed addressing particular development issues such as concurrent product/manufacturing process development. The matrix of matrices method therefore involves evaluating the wants and needs from different customers and integrating concept selection techniques to objectively evaluate alternative designs. From this perspective it is probable that the matrix of matrices method allows for a more detailed understanding but the four-phase approach affords greater practically in implementation and is therefore more applicable in the majority of situations.

The proactive approach of QFD to establishing and improving quality is in accord with continuous improvement techniques such as PDCA and DMAIC and it is possible to envisage the use of QFD within a continuous improvement cycle. This is confirmed within the *QFD Handbook* where it is stated that “QFD practitioners use the PDCA cycle to create a design flow” (ReVele, et al., 1998 p.32). This integrated approach has the advantage of establishing the relationship between the design process and the functions of the organisation. Furthermore, it illustrates that a structured cycle of continuous improvement can be used to eliminate problems or optimise service provision. Marsh et al., (1991) further demonstrate flexibility in the use of QFD by discussing the amalgamation of the matrix of matrices and four-phase approaches. Zultner (1992) extends this through the adoption of a “blitz” approach in which only significant customer requirements are included within QFD for consideration. This method does offer the advantage of providing focus on the crucial characteristics of a product or service and this is particularly important where provision is diverse (such as education).

Several studies have highlighted attempts to use QFD within an educational context. Pitman, et al., (1995) demonstrated the successful application of QFD in education in order to measure customer requirements to direct organisational resources towards customer satisfaction. Mazur (1996) used QFD in the design of a TQM course at The University of Michigan and this study is particularly powerful in that both internal and external customers are considered. This study also illustrates how the required service features of the customers (tangible and intangible) can be translated through the use of QFD into curriculum features. Comprehensive curriculum design should also consider the methods of delivery such as preferred learning and teaching styles. This problem is highlighted by Ermer (as cited in Singh, et al., 2008) who used QFD to discover disparity in teaching processes between student and staff expectations.

2.3.3.2 Failure Modes and Effects Analysis.

Failure Modes and Effects Analysis is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process or a product or service (The American Society for Quality, n.d.). Specifically in relation to service provision, evidence for the successful use of FMEA is available. Vermillion (2007) used FMEA to enhance the service offered to customers by redesigning an investment management website. Rotondaro (2001) also demonstrates successful use in a service environment of FMEA to enhance customer satisfaction in a restaurant. These studies demonstrate the flexibility of FMEA in that it can be used at the design stage or at the processing stage. Therefore, in relation to the design of a new curriculum proposal, opportunities for its use do exist. Use of a structured, iterative and analytical method to identify and prevent potential failure modes could for example be used to ensure that curriculum design features accurately reflect customer requirements and ensure that they are deliverable without issue. However, it is clear that FMEA would, if used in this manner, be used after customer requirements had been established (say through the use of QFD). This contrasts with traditional curriculum design methods where programme evaluation is located at the end of the design cycle.

2.4 Review of approaches to TQM.

The possible synergy of curriculum design and TQM has been established. To allow for further investigation the elements of TQM were defined as management values and systems, analytical tools and techniques and customer focus.

Management values and systems/analytical tools and techniques.

Research has produced evidence that providers of education favour an approach to quality management which involves the use of systematic frameworks, audit cycles, organisational assessment methods (such as EFQM and specific quality awards) or quality management systems such as ISO9000. It is likely that the widespread use of explicit standards and learning outcomes has directed the providers of education towards a standards-correction approach to quality. Advantages in the use of a management systems approach to quality management within education have been identified including its flexibility in accommodating the diversity of stakeholder requirements and its familiarity in terms of traditional management practices. This conservative approach to innovation does however present issues in relation to continuous improvement in overcoming innate defensiveness and a desire to maintain a status-quo.

Specifically relating to the use of ISO9000 other issues have been identified such as its often overly bureaucratic approach in implementation and that specialist and widespread knowledge of the requirements of the standard are required. Taken together these factors also add unnecessary costs for an organisation. Considering the EFQM model it is clear that it possesses considerable flexibility in use. This flexibility does however present difficulties in itself in that it may be difficult for host organisations to incorporate elements of the curriculum development method effectively and still maintain a clear understanding in terms of its use.

The management systems approach to quality contrasts with a data-driven, process-centred approach more typically used in the industrial and commercial sectors.

Applicable process-based methods were considered to be PDCA, DMAIC and Hoshin Kanri and each was investigated in turn. It is arguable that the providers of education tend to discount a process-based approach to quality management because of perceived limitations in application and a lack of practitioners within the field. Clear advantages to a process-based approach have however been identified. Firstly, a systematic and process-based approach is synergistic to existing curriculum planning techniques and this is particularly evident in comparison of PDCA to Tyler's curriculum planning method. Secondly, by identifying educational provision as a process (which is fundamentally about change within individuals) rather than an end-product (outcome) an opportunity exists to ensure curriculum planning becomes increasingly responsive to changing requirements. However, the potential use of DMAIC appears to present difficulties due to its analytical nature and the fact that it is more typically used in conjunction with specific improvement tools such as Design of Experiments, Statistical Process Control or Analysis of Variance. These techniques may be more difficult to implement in an educational context and consequently little evidence was found to demonstrate the successful use of DMAIC.

Hoshin Kanri is a powerful tool which can be used at either a strategic or operational level within an organisation. In terms of this thesis it is considered possible to utilise Hohin Kanri as an alternative to PDCA by cascading down information about customer requirements through the organisation. Subsequently, it would be possible to select suitable processes and methods to satisfy the overall objectives established. However, evidence suggests that Hohin Kanri would be less effective than PDCA since it is more typically associated with achieving strategic objectives and is therefore less dynamic in reflecting changing student and employer requirements.

In returning to the possible use of PDCA it has been demonstrated that despite evidence of its successful use within education for curriculum design that problems have also been identified. Particular issues have been highlighted with regard to ensuring how the demands of various stakeholders can be accommodated and how wider curriculum features (such as details of assessment and preferred learning and teaching methods) are identified and used. These issues are related to the identification of learning aims and objectives (the customer requirements) and their translation into curriculum features. Consequently, the use of Quality Function Deployment, Failure Modes and Effects Analysis and Benchmarking was investigated as a means of investigating, translating and satisfying customer requirements.

Customer focus

Evidence exists for the successful use and applicability of Quality Function Deployment in the area of service provision. Firstly, QFD is able to accommodate the diverse and complex nature of customer demands. Secondly, unlike many other quality techniques (such as DoE or SPC) it does not attempt to minimise variation and hence reduce loss. Instead QFD seeks to maximise performance and customer satisfaction. This consideration is quite clearly in accord with the provision of education by placing the customer at the centre of its thinking. FMEA is an established technique widely used in design to identify and prevent potential problems. However, FMEA is generally more applicable in interpreting and proving designs in relation to previously established customer requirements rather than actually establishing the customer requirements.

2.5 Outline proposal.

Problems regarding poorly designed curricula failing to prepare employees for industrial and commercial roles have been demonstrated. The synergy of elements of TQM and traditional curriculum design offers a solution to these problems. The issue confronting providers of education is therefore one of quality management. Providers must know how to anticipate and understand employer requirements and be able to practically translate these requirements into a deliverable curriculum package.

In relation to the provision of engineering education (within the 16-18 year age group) the premise adopted within this thesis is that the dominant role of education is to prepare students for specific roles and activities within commercial and industrial organisations. This philosophical perspective is consistent with a prescriptive approach to curriculum planning which been shown to demonstrate clear advantages in relation to a market-lead and outcomes-based approach to curriculum planning. However, by adopting an entirely prescriptive, utilitarian approach, meeting the needs and aspirations of all individuals will not be fully met. Any new curriculum method must have the inherent flexibility to accommodate contemporary practices and allow employers and employees alike to reflect upon and learn from societal changes and be dynamic and evolving to accommodate changes in conditions and learner requirements. However, it must also be practical and useful and of benefit to educators in designing curricula. In this sense it should reject reductionism and an apathetic approach to education.

Relating to wider student development it has been demonstrated that education can not merely be seen as a commodity and reduced to a number of specific behavioural objectives and here the incorporation of progressive elements to the design process have been highlighted as advantageous. A pragmatic and process-driven approach which identifies the complex relationship between educational inputs and outputs would therefore be suitable. Opportunities have been shown to exist for the use of PDCA through a systematic yet flexible framework which encourages change without over-emphasizing an analytical approach and allows for the inclusion of wider social, political, cultural and organisational issues. In particular the curriculum development method should be able to identify and translate customer requirements into meaningful deliverables and here the proven technique of QFD would appear to offer a significant opportunity. Thus, it is anticipated that through fundamentally understanding key customer requirements relevant educational objectives (ability domains) can be established within a complementary semantic structure.

In summary, what has been highlighted is the requirement for a pragmatic approach to curriculum content which is reflective and deliberative. Coherent and morally defensible decisions need to be made (based on the requirements of the students and employers) and assistance provided at arriving at sound practical judgments concerning the selection of course content and of teaching and assessment methods.

2.5.1 Aims and Objectives.

The aims of this research are to realise the synergy of curriculum design and TQM by:

(i) Developing an integrated curriculum design method.

(ii) Practically apply the curriculum design method in relation to a number of selected engineering companies within the South Wales region and produce an appropriate curriculum proposal for the provision of engineering education within the 16-18 year age group.

In relation to the application of the curriculum design method the specific objectives are to:

(a) Identify the key economic, technological and occupational drivers impacting on engineering companies within the UK.

(b) In relation to objective (a) to determine a suitable competency profile with respect to the education of 16-18 year olds.

(c) Determine the relative importance of specific competencies with respect to a range of selected engineering companies from the South Wales region.

(d) Critically review established curriculum planning methods and learning theory and determine suitable features for the final curriculum proposal.

(e) Determine the preferred learning styles, learning methods and assessment methods of the current engineering student cohort at Coleg Sir Gâr for inclusion in the final curriculum proposal.

(f) With respect to a range of selected engineering companies from the South Wales region to evaluate the effectiveness of existing provision in comparison to the curriculum proposal.

(g) Compare and contrast the existing apprentice framework against the final curriculum proposal.

CHAPTER 3

DEVELOPMENT OF THE INTEGRATED CURRICULUM DESIGN METHOD.

This chapter is used to develop and justify the integrated curriculum design method. To allow for the practical implementation of the design method an appropriate research methodology is then formulated and presented. Subsequently, specific research methods are selected and justified with a critique of the entire research methodology offered.

3.1 The integrated curriculum design method.

This thesis proposes a five-stage approach based on the use of PDCA. A two-phase modified application of Quality Function Deployment is incorporated in order to establish what are termed product and curriculum matrices. The linear characteristics of the method are to a limited extent similar to the objectives-based curriculum model developed by Tyler (1971) and are therefore complementary and familiar to established organisational quality assurance methods. However, by using PDCA as a framework the method freely accommodates the use of both qualitative and quantitative TQM tools. Thus, by integrating PDCA, QFD and traditional curriculum design, it has been possible to provide for a flexible mechanism which can determine and quantify customer requirements, translate these requirements into a deliverable curriculum proposal and provide for on-going quality assurance (see fig 3.1).

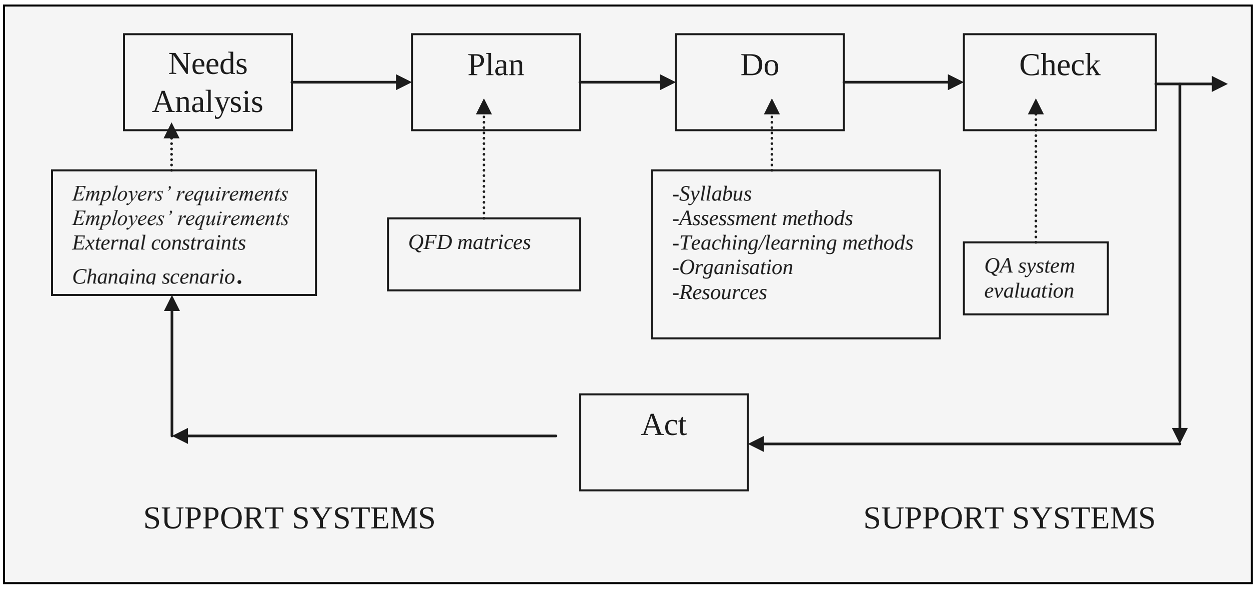

Figure 3.1 The devised curriculum design method.

As shown in figure 3.2 a two-phase application of QFD is proposed. A product matrix which prioritises employer requirements is initially established. The inputs to the product matrix are salient drivers of change impacting on engineering employers.

The output of the product matrix is the identification of prioritised competencies and the teaching modules best suited to deliver the critical competencies required. Subsequently, a second matrix - termed the curriculum matrix is developed. The purpose of the curriculum matrix is to allow for the construction of a final curriculum proposal which is not only complementary to the requirements of engineering employers but also robust to external constraints and a range of possible future business scenarios. The inputs into the curriculum matrix are the results from the product matrix. Furthermore, in recognition of the importance of the students as customers the curriculum matrix is used to ensure that complementary learning, teaching and assessment strategies are incorporated in to the final curriculum proposal.

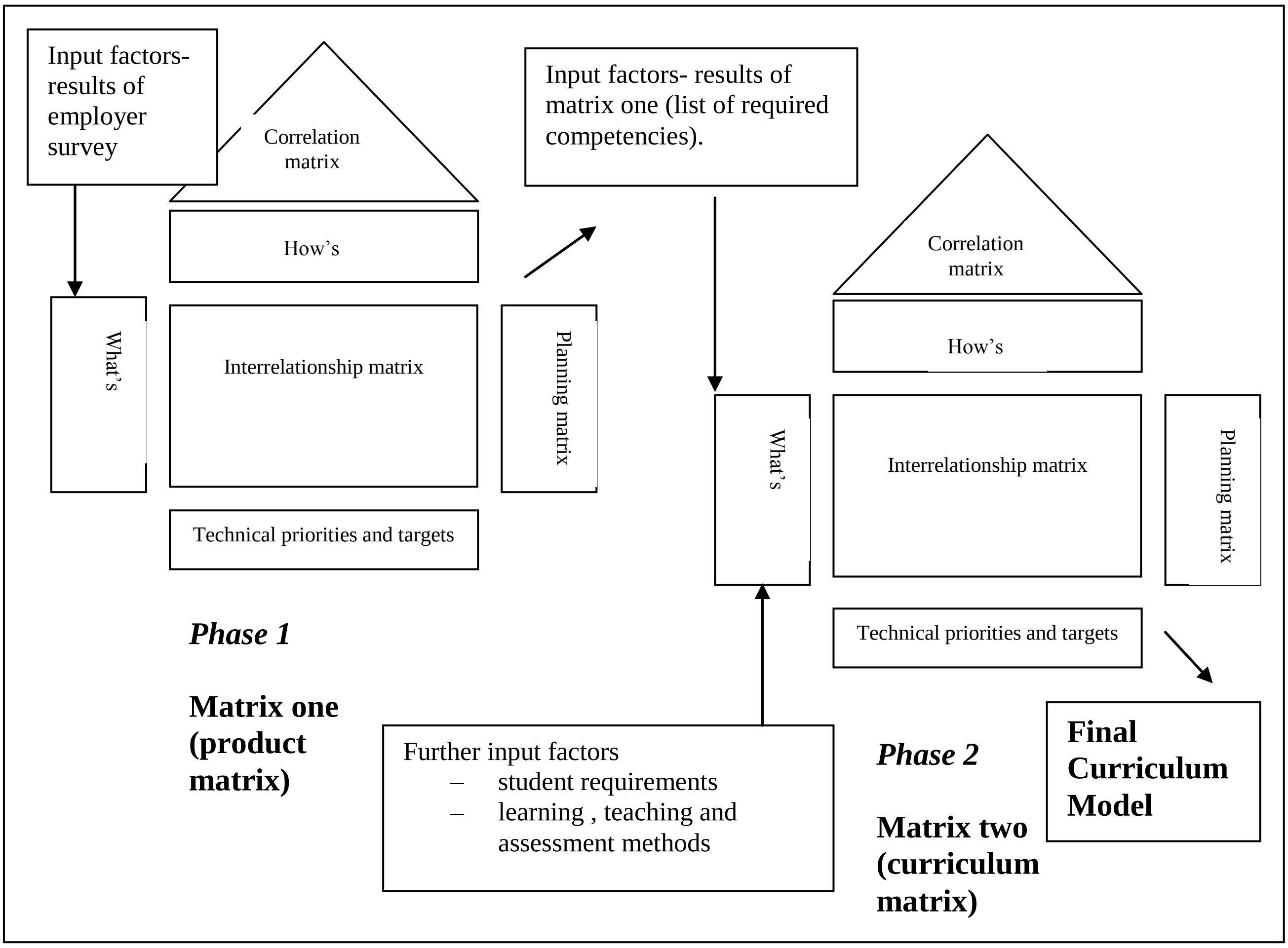

Figure 3.2. Use of a two-phase QFD model.

In providing for a practical method of translating customer requirements into a curriculum proposal QFD has been shown to be an effective and versatile tool. In comparison to traditional systems-based theorising methods (which concentrate on the capabilities of provision) its non-prescriptive approach provides significant practical advantages. In particular, by enhancing the status of the customer QFD shifts the emphasis of education provision towards a more commercial realisation that students and employers have expectations and values which they expect to receive. This market-driven approach, although controversial, is philosophically consistent with current policies on vocational education. The flexibility offered by QFD will also allow users to modify its use to reflect their own perspectives and the raison d'être of the provision. QFD is therefore easily transferable and can accommodate various educational philosophies and learning perspectives. Regardless of the individual approach taken the final curriculum proposal will achieve greater acceptance and provide enhanced customer satisfaction if the voice of the customer is accepted and translated into visible curriculum features. Thus, application of the two-phase QFD model offers a significant advantage to curriculum planners in providing a practical mechanism to relate curriculum features and learning outcomes. This contrasts to the existing situation where planners are often unable to provide for a fully justifiable explanation of the determination of academic, subject-specific and personal transferable outcomes and their inter-relationship.

The output from the curriculum matrix should be subsequently amalgamated with complementary curriculum features. Standardized curriculum features can be proposed but it is not intended that practitioners are offered a prescriptive listing. The exact inter-relationship and congruence between curriculum features and outcomes is left to the practitioner. However, through the use of QFD a profile of applicable curriculum modules and relevant skills can be established. It is therefore envisaged that the curriculum output will match its inputs and be philosophically justified.

Finally, by integrating QA procedures which recognise the fundamental requirements of the customers it will be possible to ensure provision at the gemba (workplace) is appropriate and accurately reflected. No prescriptive listing is offered and it is intended that individual institutions select and implement those QA procedures which are considered to be the most appropriate to their operation. Individual institutions are able to determine the approach best suited to their requirements although it is anticipated that quality assurance methods are formalised within the system at delivery levels. This would for example allow for monitoring at high-need intervals, directed mentoring and further student support. Furthermore, it is envisaged that the final Check and Act stages of the model would allow for standardization of delivery and assessment, sharing of best practice and the provision of feedback to the needs analysis stage.

It has also been recognised that customer requirements change quickly. By using the developed curriculum design method it is envisaged that it will be possible to go beyond existing delivery and address both the product and the management of the process to deliver it. A methodical approach to the use of curriculum design has therefore been accommodated which will allow individual institutions to maintain and change the scope of its provision through incorporating the future voice of the customer into the QFD analysis. It is intended that this process will be implemented at a strategic level where the model must be dynamic in use and the frequency of investigation carefully considered. It is envisaged that strategic use of the curriculum design method will also allow for allied techniques to be incorporated into the overall framework as required.

To allow for practical implementation of the design method an appropriate research methodology was formulated as follows.

3.2 The research methodology.

Neary (2002) identifies research methods as being quantitative or qualitative. Bell (1999) defines the difference between quantitative and qualitative research by stating that the quantitative approach involves the use of data typically collected through the use of questionnaires, experimental results and records. Qualitative methods considered include the use of group discussions, observation and personal reflection. Burgess (1993) compares the two methods by stating that when considering some forms of research such as social sciences the quantitative approach can be too restrictive and in some cases can produce misleading results. The qualitative approach can be regarded as too subjective and biased in some instances. In selecting the most appropriate method there is no best method of research and researchers need to consider the research question being considered and subsequently the most suitable methods of research and data collection can be selected (Burgess, 1993). Allison, et al., (1996) stress the importance of determining the research question and state that the research question must be set as to be meaningful and answerable.

Allison et al., (1996) further categorise quantitative and qualitative research methodologies as being philosophical, historical, descriptive, experimental, phenomenological or practical. The most appropriate category for this thesis is descriptive as the research question indicates that the purpose of the research is to determine and use quantitative data from students and employers. Considering the research question further in terms of descriptive research, the need to provide for quantitative data and the selection of appropriate research methods was highlighted and a data collection strategy constructed. This may be considered by some as overly positivist but as no attempt is made to supplement the pedagogy of teaching and learning the research is essentially concerned with optimising outcomes this is therefore a valid approach. Much of the implementation of the curriculum design method does however concern opinions, experiences and personal objectives. Here a more interpretive approach was required. This is particularly evident with regard to identifying the salient drivers of change impacting on the engineering industry (see chapter 3.2.1) and the consideration of learning theory and related curriculum planning issues (see chapter 3.2.2).

3.2.1 Research on the requirements of engineering employers.

Firstly, a chronological review is completed to evaluate the changes (categorised as economic, technological and occupational) taking place within the UK engineering industry. Thus, it was possible to develop a timeline from what can be termed the current economy through to the future economy. Through the use of this chronological approach it was subsequently possible to construct a historical perspective of the engineering industry and forecast future scenarios. At each point in this chronological sequence the individual aims and objectives of the project was considered with the areas of review being:

- A review of the UK engineering industry.
- Forecasted trends within the UK engineering industry.
- Characteristics of world class engineering industry;

The results of this review are described in chapter 4 of this thesis.

Secondly, original data was collected to supplement and confirm the salient findings of the initial review. This data was gathered from a range of engineering companies within the South Wales region. It was considered that the supplementary information would allow for further analysis into how individual companies across a range of engineering sectors (as defined in the Puttick grid, see chapter 4.4 for details) have responded and will continue to respond to the drivers of change identified. The approach used was to cross-reference the relevant economic, technological and occupational drivers of change against specific competencies required to manage them. The competencies were categorized as technical skills, professional and business skills, information handling skills or generic skills. Within each of these general areas specific competencies considered to be of importance were identified.

Following the identification of relevant competencies it was possible to design an employer questionnaire (see appendix 1) and pilot it through a range of local employers to ascertain their actual requirements for the future. The employer questionnaire was designed to allow for the investigation of individual employer details (and their business profile within the Puttick grid), required competencies (specified as manufacturing, professional and business, information handling and generic) and apprentice recruitment and education. This information was subsequently utilised within the QFD matrices as a series of rated customer requirements (see chapter 6 for the results of the employer survey).

The use of a questionnaire was considered to be the most suitable approach. This is justified in terms of efficiency of time, accuracy of results and in allowing for a statistical analysis of the results to be completed. It was recognised that much of the information to be gathered would be reliant upon the response of the interviewees and therefore largely subjective. In order to make the information more quantifiable (and allow for statistical analysis) the questions were constructed in a manner to allow for the answers to be presented as either a simple percentage or in the case of questions requiring more qualitative responses the data was changed to variable (quantitative) data through the use of the following marking scale.

(1= not important to 4 = very important).

Not important Very important

1 2 3 4

Owing to the small sample size an even number of possible responses was selected to ensure the absence of neutral answers.

The questionnaire was designed in line with recognised good practice (Sekaran, 2001). The questionnaire was initially tested before release to ensure the structure and wording of the questions was appropriate to the level of the understanding of the respondents and constructed to be without bias and avoiding the use of slang or jargon. It was also necessary to consider ethical factors and in particular the possibilities for personal bias within the research as well consent issues and any effect of the research on the learners (see appendix 4).

3.2.2 Research on learning theory.

In order to ensure that selected elements of the final curriculum proposal would be established on and supplemented by widely accepted and applicable learning theory it was necessary to complete a review of learning theory. The salient areas of the review were selected to be complementary to the aim of the research and were therefore primarily concerned with a review of curriculum modelling and planning theory. Furthermore, since it was anticipated that the output of the QFD matrices would include the identification of appropriate teaching and assessment methods the review was extended to encompass perspectives on learning, factors affecting learning and learning styles. Finally, to evaluate the final curriculum proposal against current provision an investigation of existing provision was also completed. To allow for a further comparison of the final curriculum proposal this investigation was extended to include the existing apprentice framework (see chapter 5).

3.2.3 Research on the requirements of engineering students.

In terms of the engineering students it was envisaged that an investigation would allow for the consideration of the effectiveness of current educational provision and establish the educational requirements of students. The most appropriate method for gathering this information was again considered to be the use of a questionnaire.

The student questionnaire (see appendix 2) was designed to allow for the investigation of three areas of research. Firstly, the preferred learning and assessment methods of the students were determined. Secondly, the professional and personal aspirations of the students and the level of correlation between student and employer expectations were investigated (this research was to determine any inconsistencies in the learning expectations between the students and employers and determine the long-term ambitions of the students). Thirdly, recruitment issues were investigated. The purpose of this research was to determine the perceptions of students of engineering and engineers, the reasons for students deciding upon engineering as a career and to determine after experiencing engineering education whether they would recommend it to potential students. Furthermore, it was decided that additional information regarding the preferred learning styles of engineering students would be gathered. This was considered beneficial in that it would allow for refinement of the input into the QFD matrices (see chapter 7 for the results of both surveys).

In respect to determining the preferred learning styles of the students it was decided to utilise the method as proposed by Honey and Mumford (1982). The use of this method is justified due to its relative simplicity in use, in reflection of the practical nature of the programme area under investigation and previously agreed copyright gained by the University (see chapter 5.4 for further details).

Figure 3.3 illustrates the entire research strategy used by superimposing the selected research methods upon the developed curriculum design method.

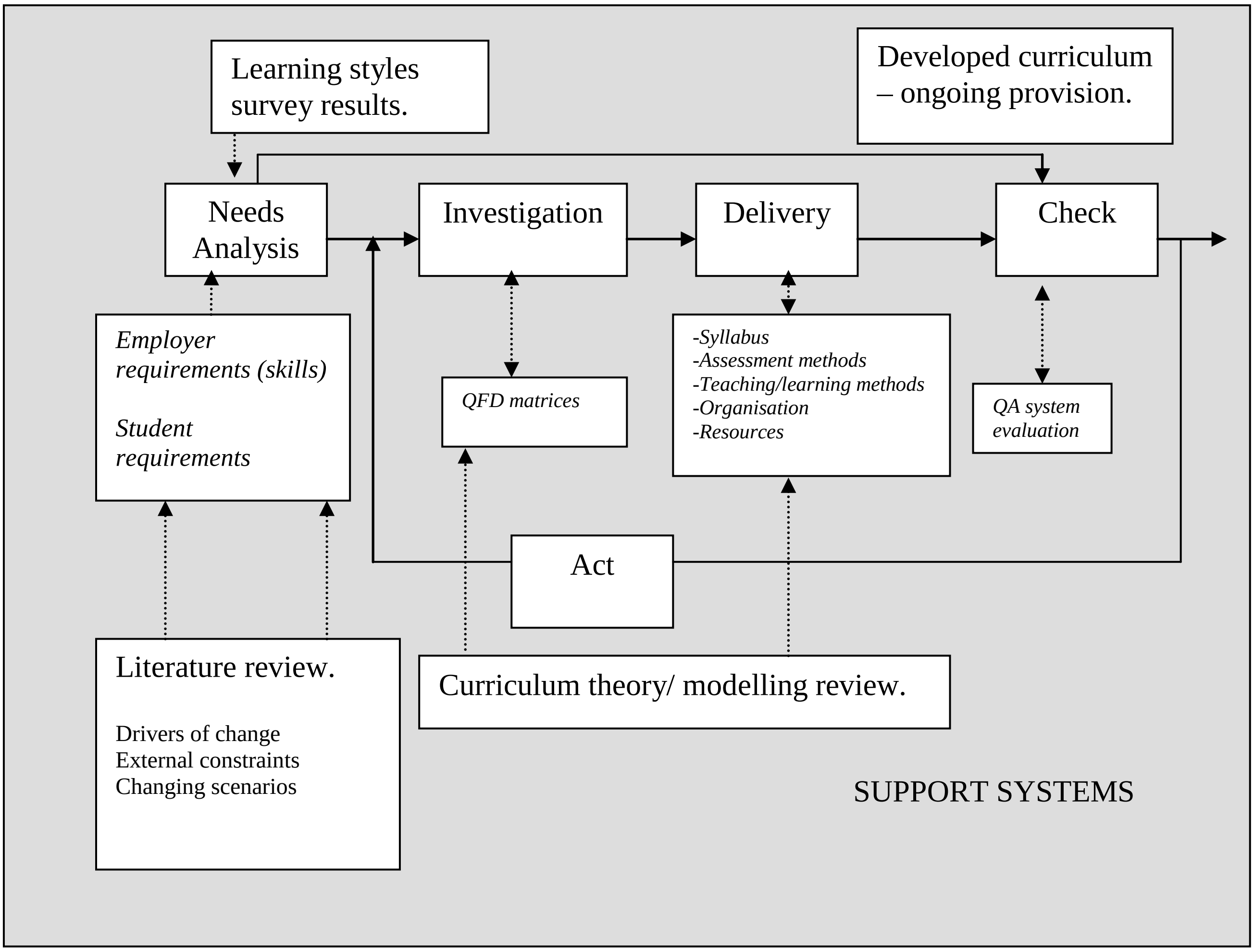

Figure 3.3 The research methodology.

3.3 Critique of the research methodology.

The research methodology was successful. Primary data was collated from employers and students which was not previously available and here the use of questionnaires did prove effective. The design of the questionnaire produced results that were quantifiable and allowed for statistical analysis. In hindsight, it may have been beneficial to extend the interview process used with employers to further explore more subjective issues.

The scope of the study was limited to students at Coleg Sir Gâr and employers within the South Wales region. Consequently, the sample sizes used were small and by extending the study to other colleges a greater sample size could have been obtained. In terms of secondary data the literature reviews were completed effectively but greater effectiveness could have be gained through utilising a multi-disciplinary team consisting of key personnel. This would have afforded a broader consideration of factors and may have lead to a more rounded analysis.

3.4 Chapter summary.

Synergy of the TQM techniques of PDCA and QFD and traditional curriculum planning theory offers the possibility of providing educators with a fundamental understanding of customer requirements and a practical mechanism for their delivery. A theoretical curriculum design method based on the use of PDCA which incorporates a two-phase modified use of Quality Function Deployment has been proposed and philosophically justified. To allow for the practical implementation of the design method the formulation of an appropriate research methodology based on interpretive and descriptive methods has been proposed and specific research methods identified and described.

CHAPTER 4

IMPLEMENTATION - A CHRONOLOGICAL REVIEW OF THE ENGINEERING INDUSTRY WITHIN THE UK.

To construct the final curriculum proposal it was necessary to firstly examine the drivers of change affecting the UK engineering industry. Thus, this chapter should be considered as an interpretive reflection rather than a traditional literature review. Within this chapter the general context of engineering activity within the UK is examined and a chronological review subsequently completed in order to forecast possible future scenarios. The output of the chapter is a listing of the salient economic, occupational and technological drivers likely to impact on UK engineering industry in the future.

4.1 The context of engineering industry in the UK.

Livesey (2006) identifies manufacturing and services as the two major components of the UK economy. Although these broad definitions do not identify engineering activities specifically it is clear that engineering industry is a sub-sector of manufacturing. This is confirmed by sectorial definitions within manufacturing supplied by The Organisation for the Economic Co-operation and Development (OECD) in its *Economic Survey* (2004) in which the mechanical engineering, electrical engineering, automotive engineering and metal processing engineering industries are identified as sub-sectors within manufacturing with significant engineering content. An analysis of the contribution of these engineering sub-sectors to total UK manufacturing wealth is also provided and is shown in table 4 (i).

Sector classification	**Contribution to manufacturing wealth (%)**
Engineering	
Electrical engineering	15
Metal processing engineering	11
Automotive and transport engineering	10
Mechanical engineering	6
Total of engineering sub-sectors	*42*
Other manufacturing	
Publishing and print industries	15
Food and drink manufacture	13
Chemical products	10
Textiles	6
Plastics/ rubbers	5
Others	9
Total for other manufacturing activities	58
Total	100

Table 4(i) – Contribution to manufacturing wealth.
Source: OECD 2004

Economic recessions in the 1980's and 1990's considerably affected manufacturing industry. During this period manufacturing as a percentage of UK GDP contracted from 30% in the early 1970's to less than 19% by the end of the 1990's Office of National Statistics (ONS) (2007). The decline of the manufacturing sector has not been restricted to the UK and many other major western industrialised nations have also seen a shift in economic activity away from the manufacturing sector to the service sector, Economic and Social Research Council (ESRC) (2004). Wilson (cited in Connor, et al., 2001) in considering the various engineering sub-sectors demonstrates the significant decline in employment from 1971 projected through to 2010 (see fig 4.1). This work is helpful in illustrating the scale of the decline in engineering industry but it should be put in context since the traditional classification of engineering as being within the secondary sector is becoming less meaningful. In particular, organisations have recognised the importance of services, research and development and the provision of data/information as part of the overall provision to customers. The true contribution of engineering to the national GDP and employment levels should therefore take into account additional revenue through the provision of supplementary pre and post-production services (Kowalkowski, 2005).

Despite historical losses in total employment levels, the UK Government stated in its *Working Futures* report (2003) that the GDP of the engineering sector is forecast to grow through to the year 2012 at an average of just under 2% per annum. Wilson (2000) provides support by writing that during this period higher growth in the technology and research and development areas of engineering is expected but other sub-sectors will perform less strongly.

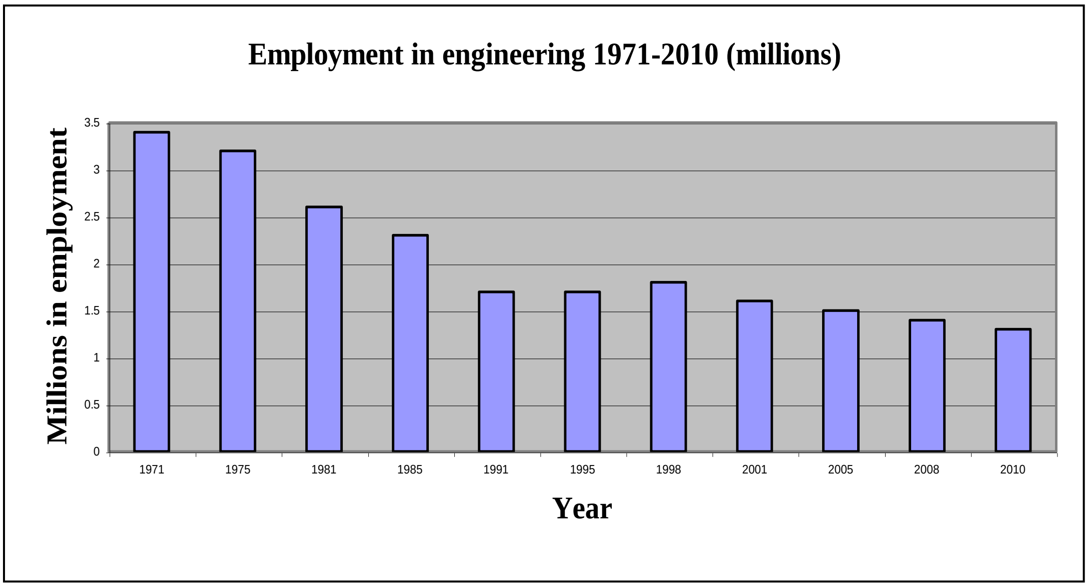

Figure 4.1Employment levels in engineering within the UK (1971-2010). Source: Wilson 2000 cited in Connor, et al., 2001, p. 11

Wilson (2000) further forecasts that metal manufacturing and other labour intensive industries will be one of the weakest performers (where exposure to higher labour costs compared to foreign competitors will be compounded by the price sensitive nature of the sub-sector). In relation to Wales this is likely to be significant although greater diversity in the manufacturing base (which is now less dependent on traditional steel manufacture) may result in a smaller decline in total employment.

The previous studies illustrate the continued importance of macroeconomic conditions on the performance of the UK engineering industry. The ability of UK engineering companies to survive will depend to a large extent on what happens in the future to key economic indicators. In relation to this thesis macroeconomic effects will therefore have to be factored into the final curriculum proposal and preventative and contingent actions considered. The *OECD Main Economic Indicators* provide a basis for further consideration and those relating to this thesis have been taken to be taxation levels, exchange rates, the inflation rate and the interest rate. Chapter 4.1.1 is used to discuss these issues in more detail.

Further studies have highlighted the significance of ensuring internal cost structures are appropriate to the market sector. Particular challenges are being presented by Far Eastern and Eastern European economies where the presence of lower labour rates present significant advantages over UK based manufacturers (Institute of Mechanical Engineers) (ImechE) (2008). Brazil, India and China in particular have significant labour cost advantages over UK companies and are expected to experience significant growth over the next decade, EEF (2008). In light of these challenges engineering organisations have been forced to reassess their roles as greater competition from low/medium wage economies and the effects of globalisation take hold. Many UK engineering companies may choose to relocate to these lower cost locations and exploit this important advantage as well as obtaining access to a network of cheaper suppliers and the local market itself. In particular, companies at the lower end of the technology scale (which are driven by labour costs) will have to consider this possibility (PricewaterhouseCoopers, 2008). The importance of controlling internal cost structures has therefore been demonstrated and will also need to be factored into the final curriculum proposal. In relation to this thesis the key indicators of internal costs are taken to be manufacturing and labour costs and these allow for further investigation (see chapter 4.1.1).

Wherever the location of operation, to remain effective within the new global environment, engineering organisations will have to adapt and become more flexible. Cheng (2004) views this as a strong driver in which localised production units will need to become more self-sufficient in order to minimise lead times and maintain competitiveness in terms of cost. In this scenario the role of centralised design and management facilities within some organisations may need to be reconsidered and greater autonomy devolved to local production units. Increasing integration and partnership working with suppliers will also mean that small firms within the supply chain will be expected to undertake work of a more complex nature as larger organisations look to outsource work. Original Equipment Manufacturers will seek to increase the scope of work undertaken by suppliers with the trend to modular supply set to continue. This is already evident within the automotive sub-sector in which manufacturing clusters have developed to cooperate in technical and commercial areas (Parker and McGinity, 2006). An increased level of supply chain integration illustrates the requirement for the potential acquisition and development of broader skills such as project management, communication and the management of change.

Further complexity in the overall situation is evident. Engineering companies in the UK are diverse with over 90% of engineering establishments employing fewer than 50 people but accounting for approximately 30% of total engineering employment. Only about 1% of establishments employ more than 250 people, but these account for 37% of total employment EEF(2003). This is supported by the UK Government in its *Manufacturing Strategy* (2002) and the *Working Futures: National Report* (2003) which identified that engineering industry in the UK (in comparison its major competitors) suffers from a larger proportion of small companies, low levels of skills, low productivity levels, comparatively low investment in Research and Development (R&D) and low returns on investment. These reports demonstrate the

inter-relationships between economic, technological and occupational factors. This can be illustrated by the relationship between supply and demand and an understanding that this relationship is critical to the continued success of any organisation involved in engineering (Sweeney and Szwejczewski, 1995). On the demand side engineering companies need to carefully consider economic and technological customer requirements including price, quality, function, safety, environmental impact, serviceability, and reliability. On the supply side engineering companies are required to review cost and occupational structures for suitably designed and manufactured products to satisfy the explicit and indeed in many cases implicit customer demands. Engineering companies therefore develop an understanding of the life-cycle of their products (as determined by customer requirements) and are able to transform these requirements into tangible outputs, through the control of suitable processing and management methods.
The effect of technological and occupational drivers is therefore evident and again their potential effect must be considered and factored into the final curriculum proposal. In relation to this thesis the key technological drivers have been taken to be the level of productivity, the effect of new technology and life cycle management (see chapter 4.1.2). The salient occupational driver has been taken to be changing occupational profiles and the resultant effect on occupational, vocational generic skill acquisition (see chapter 4.1.3).

In describing the context of engineering industry within the UK a complex and multi-faceted situation has emerged in which economic, technological and occupational factors combine. Clearly, the exact challenge facing UK engineering companies in the future will depend on how the economic, technological and occupational drivers identified fully interact. The challenge within this thesis was to establish a listing of drivers (and the skills profiles that will be required) which will be sufficiently robust to the any possible future scenario.

4.1.1 Economic drivers.

Levels of corporate income tax, employer social security payments and Value Added Tax (VAT) within the UK have compared favourably with major competitors, *The Tax Misery Index* (Forbes, 2003), see figure 4.2. Thornton (2006) views this as an important factor in terms of continuing to attract both foreign investment and encouraging internal investment (which is in turn is again linked to raising productivity). Görg (as cited in Stott, 2007) however disputes this and views higher taxes (and higher public social expenditure as a proportion of GDP) as advantages to potential investment. Nevertheless, taxation costs must be considered as an external constraint and organisations will need to develop strategies and skills to manage its impact. This may prove problematic to some organisations as the historical advantage of lower taxation levels within the UK has eroded relative to many other countries OECD(2007).

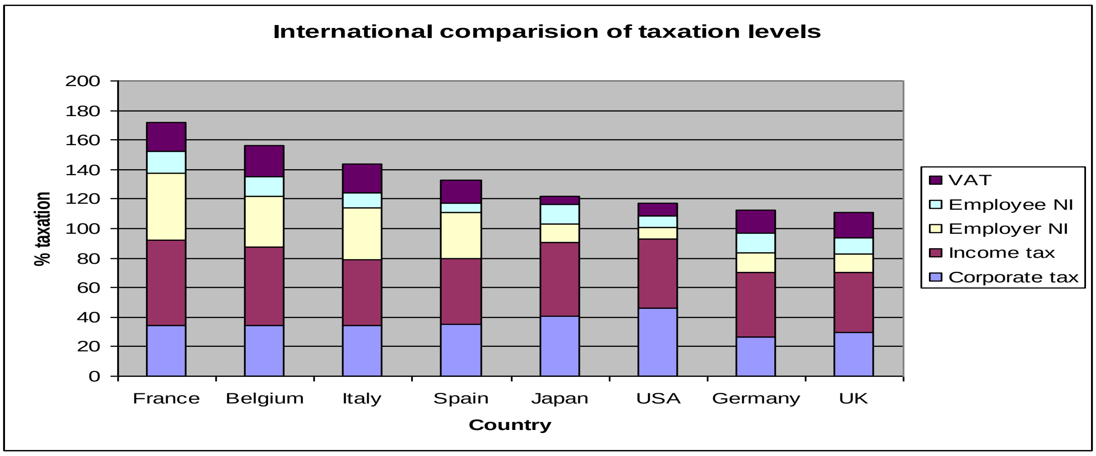

Figure 4.2 International comparison of taxation levels.
Source: Forbes (2003)

Data from *competitive analysis report* (KPMG, 2002) into international competition confirmed that the UK has enjoyed a significant advantage when comparing manufacturing costs (based on labour costs, taxation costs and utility costs) with major competitors. Furthermore, the total cost to employers after taking supplementary costs such as National Insurance into account has been one of the lowest in the EU, OECD(2004). This has afforded companies operating in competitively priced markets an advantage over international competitors. However, it is arguable that this advantage has lead to overdependence on labour intensive production. This is a problem compounded by the lower level of labour regulation within the UK and is therefore likely to be a major issue in raising the productivity of our engineering base. Leitch (2006) highlights this issue and recommends that competitiveness within the UK should not rely on low labour costs. Nevertheless, manufacturing costs will remain a critical metric in the future (particularly in relation to labour intensive industries) and the acquisition of commercial and financial skills can be tentatively noted for inclusion within the final curriculum proposal.

The competitiveness of the UK engineering sector has to some extent been undermined by the volatility of the UK inflation rate as well as its high rate compared to our major international competitors ONS(2009). There has however been a significant stabilization in the inflation rate since the mid 1990's and currently the UK rate of inflation compares favourably with those of our major competitors (Porter and Ketels, 2003). The stabilisation of inflation since that time has to a large extent also helped to remove the wage-price spiral noted in the 1970's and 1990's and helped to increase the productivity of UK engineering industry. Furthermore, decision-making in respect of capital investment has been made easier as organisations are able to plan for a more predictable future with clearly identifiable borrowing costs.

Interest rates have been at historically low levels since the late 1990's (Bell, 2005). This reflects the low inflation rate and stable consumer demand in the market place since this time. Since 2008 however, higher interest rates have been experienced and this will inevitably affect borrowing repayment levels as well as demand generally within the economy. Engineering companies specifically involved in supplying to end-users or the housing market are likely to be affected most directly but the general demand in the market place will also be adversely affected by higher rates. Also of significance is that any increase in interest rates for companies exposed to high borrowing levels will not only result in increased bank repayment levels but could have an adverse effect in terms of investment in research and development. Furthermore, any increase in interest rates may cause an appreciation of the exchange rate which in turn leads to a fall in the demand for exports and thus reducing aggregate demand. Companies heavily dependent on exports or the importing of raw materials could therefore be adversely affected.

The UK economy remains vulnerable to exchange rate fluctuation (Irvin, n.d.). It is significant to point out that many of the previous macroeconomic advantages would be lost if sterling was to appreciate excessively, relative to competitor countries. Conversely, depreciation in sterling would afford UK engineering an additional advantage. The importance of the exchange rate was evident in period from 2004-6 when the strength of sterling had the most direct impact on the engineering sector in making exported goods more uncompetitive and imported goods more competitive

OECD(2004). Other detrimental effects of an over-valued pound should also be acknowledged included lower investment, increased sourcing from overseas and the migration of production abroad. The introduction of the single market within the European Union also resulted in UK engineering companies being disadvantaged compared to continental manufactures by virtue of having to incur currency transition costs and in this respect an important consideration in the near future will be whether the UK decides to join the Eurozone or not. Additionally, although fluctuations in currency rates can be either advantageous or disadvantageous, the additional uncertainty makes it difficult for UK manufacturers to plan ahead.

Summarizing the previous information the key economic drivers for the future are considered to be as follows.

- Sensitivity to changes in the level of interest, taxation, inflation and exchange rates will continue to be of prime importance to engineering organisations. The degree to which individual companies are affected by any rate changes will however depend on the individual circumstances within that organisation. It is anticipated that continued pressure from economies with lower labour costs will result in some UK engineering companies having to be increasingly competitive in terms of added value. Specifically, this will be in terms of service, quality, flexibility and technical knowledge. Managing these challenges will continue to be met though good business awareness, commercial and profit focus, business development skills, strategic business planning and financial control management abilities.

- Labour costs will continue to be important in sectors where competitiveness in terms of price will remain the key factor for continued success. In the higher technology sectors it is expected that increased use of automated and advanced technology will increase the ratio of indirect to direct costs as companies look to satisfy the increased level of customer satisfaction demanded. Specific areas were indirect costs are likely to increase include design, process control, information handling, logistics, customer service and support and supply chain management. Interpreting these issues the research therefore identifies the need for business awareness and commercial and profit focus, customer service activities are business development, customer focus, persuasiveness, communication skills, building relationships and integrity.

- Despite the concerns regarding the effects of globalisation it is important to note that many engineering companies in the UK operate with only a local and/or regional customer base. Many of these firms are small and medium sized engineering companies and it is clear that if the UK economy remains focused on short-term profitability then price (rather than quality, customisation or specification) will remain the key driver for many of these companies. Satisfying this market will therefore continue to be a strategy based on price with a standardised products base probably with a low paid and low skilled workforce. These companies will continue to be focused on costs, prices, organisational structures and management systems, rather than the need to improve occupational and professional skills.

- Some engineering companies will become more service driven and may need to reorganise their supply chain management and customer service provision. Coherent business strategies will need to be developed and implemented by managers and engineers alike. Probable areas of concern will include supplier partnerships and outsourcing arrangements, the possible acquisition of competitors, return on investment, control of costs and appropriate product pricing through a clear marketing policy. Although many of these skills are primarily required by senior employees it is anticipated that organisations will require all staff to become more commercial aware. This will be the case regardless of the sector the individual organisations operate within. With regard to these issues the research identified the need for business awareness, commercial and profit focus, business development, logistics and supply chain management, materials flow technology, customer focus, integrity, building relationships, drive and confidence.

4.1.2 Technological drivers.

Engineering industry within the UK has a large degree of diversification. A significant advantage has been the traditional strength of high technology areas such as aerospace, defence, pharmaceuticals and automotive engineering (Aydalot and Keeble, 1998). These activities afforded the UK a measure of technical advantage over competitor countries but globalisation would appear to have eroded the technology gap between the UK and developing countries**.** Data from the European Union in its *Working Document for the MANUFUTURE Conference* (2003) supports this viewpoint in showing that the share of medium and high technology production within the economy for first-world economies (including the UK) increased from only 59% in 1990 to 61% in 1998. However, the corresponding growth in developing countries shows a larger increase, from 42.5% to 49%.

Specifically within the UK the erosion of this technological advantage has resulted, at least in part, through general underinvestment within the engineering sector and in research and development activities in particular (Leitch, 2006). Supporting evidence for this assertion is provided by the UK Government in its *Manufacturing Strategy* (2002) which stated that manufacturing industry (and within it the engineering sub-sector) accounted for 80% of research and development expenditure within the UK. Despite this level of expenditure, UK manufacturing companies still significantly under spend compared to their major foreign competitors. *The Working Document for the MANUFUTURE Conference* (2003) considers this issue further and reports that as a percentage of GDP, UK manufacturers only invest 3.2 % of turnover in research and development whilst this figure rises to 3.8 % in the EU as a whole, 7.8% for the United States (US), and 8.4% in Japan respectively. Furthermore, a detailed comparison of middle-sized companies in the US with comparable UK companies indicates that the UK has less than one third of the US proportion of companies with high research and development intensity. This would appear to support the opinion that within the UK there is a significant tail of under-performing companies. Sectorial analysis did however confirm that UK companies have higher total research & development expenditure in the pharmaceuticals and health sub-sectors compared to Germany and France.

At the national level the UK government has also consistently spent less on research and development (as a percentage of GDP) compared to foreign Governments, OECD (2004). The UK government spends only 0.2% of GDP on research and development compared to 0.34% and 0.43% by the German and French Governments respectively. Importantly, the OECD notes that foreign Governmental financial support also extends to tax credits and other fiscal incentives which are designed to increase stability and the reduce risk involved in research and development activities.

Expenditure in research and development appears to be related to company performance not only in terms of sales growth but also the labour productivity per employee (Leitch, 2006). The UK Government in its *Manufacturing Strategy* (2002), details that labour productivity throughout the whole economy (as measured by GDP per hour) is about 30 per cent higher in the US and France and 17 per cent higher in Germany compared to the UK. Although the manufacturing sector comprises only 20 per cent of the Gross Domestic Product, it accounts for between 30 per cent and 40 per cent of the total shortfall in productivity between the UK and its competitors. The shortfall in manufacturing productivity was also considered to contribute disproportional to a lack in productivity across the entire UK economy.

Further analysis of the productivity gap between the UK and the US, France and Germany is shown in table 4(ii) which demonstrates the deficit in productivity within the general manufacturing sector is repeated within the major engineering sub-sectors, NIESR (2003).

	Country		
Sector	US	France	Germany
Manufacturing	155	132	129
Electrical and Electronic Equipment	273	145	135
Aluminium Products	210	218	92
Basic Metals	198	148	166
Chemicals	169	141	104
Motor Vehicles	150	200	111
Machinery	146	107	123
Rubber & Plastics	140	119	111
Instruments	133	129	125
Metal Products	110	160	138

UK taken as 100 in each case.

Table 4(ii) – International comparison of productivity (relative output per hr worked per sector).
Source: National Institute of Economic and Social Research cited in The Governments Manufacturing Strategy 2003, p.7

Reviewing table 4(ii) it can be appreciated that in some sub-sectors the productivity gap between UK engineering companies and their US, French and German competitors is very wide. This is particularly the case within the sub-sectors of electrical and electronic equipment, aluminium products and motor vehicles with some foreign competitors being twice or even three times as productive per labour hour compared to their UK equivalents. Some of the productivity gap can be explained by differences in physical capital i.e. plant, equipment, buildings and structure available to each worker. NIESR (2003) estimated that such differences in capital provision were estimated to explain about 21 per cent of the gap with the US, about 68 per cent with France and 29 per cent with Germany, see table 4(iii). It was further concluded that differences in skill levels account for the majority of the remaining gap, especially in Germany - which has a strong record in the provision of vocational skills education and training.

	US	France	Germany
Total Capital	65		54
Physical capital	21	68	29
Skills	44	#	25
UK = 100			

- Data not available

Table 4(iii) – Analysis of the UK manufacturing productivity gap.
Source: National Institute of Economic and Social Research cited in The Governments Manufacturing strategy 2003, p.15

The UK engineering industry has experienced major technological developments over the last two decades (Aydalot and Keeble, 1998). In particular the use of communications and information technology equipment as well as advanced Computer Aided Manufacturing (CAM), process automation and robotics has revolutionized manufacturing systems. These technological changes have had a profound influence on many organisations in terms of occupational profiles, employment levels and organisational structures as well as the chosen methods of working and thereby productivity rates. However, related to the generally low productivity levels within UK engineering industry is an inability to fully harness new technologies and methodologies to raise performance (Leitch, 2006). Compounding this issue many UK companies have traditionally spent any available money on acquisition rather than upon technological research and development. This is confirmed by *The Department of Trade and Industry's research and development scoreboard* (2003) which notes that UK companies spend 3.5 times more on acquisitions per pound of investment compared to their US competitors. Howver,it is debatable if acquisition does deliver step improvements in technology and productivity levels and organic growth over a longer period may be more successful.

Further technological developments are anticipated in the future and various studies have been completed investigating potential effects on the engineering industry. On the demand side, The European Union's *European report for MANUFUTURE* (2003) anticipates that advances will be made in the fields of materials science, information technology, electronics and biotechnology. The automotive industry is expected to be at the forefront in the use of new technology in which there will be increased dependence on the use of electronic control systems and advanced materials such as composites, prepregs and plastics. Other studies such as *Emerging Global Manufacturing Trends* have concluded that customisation of supply is set to increase and customers will demand products tailored to individual needs rather than mass marketing (Briggs, 2000).

Several studies have highlighted the possible effects of increasing demands for sustainable development. Detailed in *Sustainable Development and the Environment* (2003), the UK Government found that UK engineering companies will have to satisfy market demands for more environmentally friendly products and processes. Greater emphasis will require companies to consider factors such as how to develop and utilise energy and resource saving technology. Smith and Crotty (2009) confirm that companies will need to continue to reconfigure products to minimise environmental impact, provide products which match customer concerns on environmental impact, understand and comply with local, national and international socio-economic expectations and match shareholder and stakeholder values. Thus, life-cycles which take into account all of the costs associated with products over their entire life will become increasingly important as companies realise that customers now require total service provision over the life of a product, rather than merely looking at the initial purchase cost of a product. Products that support lifestyles will be required and in particular, environmental concerns will have to be addressed by designing and manufacturing products, which are recyclable and sustainable.

Increasing legislation in the areas of health and safety and environmental sustainability and management is expected and will potentially have a profound effect on engineering industries (Brentnall, 2007). Companies are therefore likely to be required to comply with stricter legislation and it is expected that regulations may be issued specifically covering the areas of emissions, waste disposal, recycling and product take-back. Many companies have already taken the initiative of introducing an environmental management system (such as ISO14001) which will aid companies in formulating procedures covering the additional regulations expected. Increased legislation will require additional skills from engineers and other employees in areas such as environmental risk assessment, contingency management and sustainability life-cycle analysis. Companies that embrace increased regulation and use it positively to improve performance will have the added benefits of improved customer and public approval as well as the opportunity to influence the legislation itself.

The World Economic Forum Global Competitiveness Report (cited in *Bridging the Continental Divide*, 2003) highlights the advantage of high flexibility within the UK labour market. Increasing legislation such as the introduction of the Minimum Wage 1999, The Working Time Regulations 1998, The Employment Regulations Act 1999, The Maternity and Parental regulations 1999 and The Employment Act 2002 are likely to have eroded this competitive advantage. The impact on the UK's engineering base will however depend on the interaction of the external constraints and internal factors. In particular individual companies will need to anticipate the impact of further legislation in relation to their area of operation.

Reviewing all the previous studies they indicate the shift in demand towards customised products will result in changes in production methods and within many companies the traditional use of dedicated mass production equipment is likely to be replaced by flexible manufacturing and computer controlled systems and a batch rather than a flow production methodology. In this respect information gathering and handling, process control and management, research and development, design and market intelligence all leading to customised added-valued products will be essential tools for the next decade. Moving up the added value chain will therefore be an appropriate strategy for many UK engineering companies. However, in acknowledging the generally low productivity levels within the UK engineering industry, increasing flexibility and occupational skills must be achieved to take advantage of these changes. Thus, it can be concluded that high wage economies such as the UK will be able to compete against low wage economies only by utilising well trained and motivated employees. Organisations will need to develop an employee culture of self-motivation and empowerment where the attainment of knowledge and the pursuit of continuous improvement are seen as fundamental to the prosperity of the business.

Taking the above factors into account it can be anticipated that companies will need to be highly responsive with regard to function, cost, quality and delivery and a balance between local customised production and the economies of mass production must be found. Clearly, UK engineering companies operating directly against companies from developing countries will not be able to compete on cost alone and therefore they must be able to compete in terms of added-value. This added-value will likely be through improved design and quality, disposability after use, and after service provision. Furthermore, increasing customisation of demand will require all business functions to increase their flexibility and reduce costs. This is likely to result in some companies needing to develop simultaneous engineering activities, supply chain relationships and internal systems which are flexible and non-bureaucratic. In this scenario, meeting and exceeding customer expectations by manufacturing tailor-made products rather than mass-produced items will become a prerequisite and product features geared to adding value in terms of design, technological features and quality will be required. It is anticipated that design and manufacturing will become even more closely connected in an effort to reduce lead-time to production and overall costs and new preproduction techniques such as rapid prototyping and the use of sophisticated software to integrate all functions in the life-cycle can aid companies. In this respect, faster communication will be possible via use of the internet and a greater understanding of this area must be mastered if UK engineering companies are to make full use of the opportunities it offers.

New business models to increase flexibility and reduce costs in the areas of sales, customer service and design will need to be developed in order to produce concurrent activities in research and development, manufacturing and the supply chain. Companies must be able to gain a profound understanding of their business, its customers and the processing methods it uses to deliver products and services.

Key metrics to consider will include customer satisfaction, internal defect rate, time from design to manufacture, productivity, investment levels, employee motivation, return on investment from training, flexibility, innovation, environmental impact, product cost and price and profitability. Organisations that gain this profound understanding will survive and prosper, those who do not, will be threatened by those companies which have. Organisations will also need to reconsider every aspect of their operation and develop a company philosophy which identifies and establishes targets for relevant metrics and a methodology for evaluating and improving performance against them. The management of information will therefore be a vital competency and areas such as design, process modelling, factory-modelling and digital to physical integrators increasing in importance. At the same time it must be recognised that the availability of intellectual capital on the Internet will remove much of the advantage larger companies have traditionally experienced and organisations may therefore need to concentrate efforts in specialist areas to gain economic advantage.

Summarizing the previous analysis the key technological drivers for the future are likely to be as follows:

- Understanding the product and services the company provide and what characteristics make it a valuable commodity to the customer. Companies must be able to ask themselves how do they measure customers satisfaction and how will they stay ahead of competition in the future?

- Process optimisation and the reduction of variability will be critical in providing products to increasingly stringent requirements. The use of advanced techniques such Design of Experiments and the Six-Sigma methodology is set to expand.

- Just-in-Time (JIT) manufacture will become increasingly required to aid flexibility as product life-cycles are reduced and this will require robust and well maintained manufacturing processes and the use of Flexible Manufacturing Systems (FMS) within a batch production environment will need to be carefully considered. Maintenance and process management functions will be critical in achieving the production of high quality, customised products as well as reduced change over times in order to maximise overall equipment efficiency and flexibility in supply.

- Intellectual capital and knowledge capture will be vital in ensuring the success of organisations in the future. Companies that are able to place emphasis on the generation and retention of knowledge and skills will have an ability to counter the threat of low wage economies. Organisations will need to ensure members of staff have appropriate IT skills (CAD/CAM simulation, rapid prototyping etc), research skills and problem solving skills. In sectors with a higher technological content these activities are expected to extend to patent generation, the control of intellectual capital and the development of new products, processes and materials. With regard to these issues this research therefore identified the need for the following skills:

business awareness, commercial and profit focus, business development, the exploitation advanced design and manufacturing technology, materials flow technology, product development and concurrent engineering, creativity, team working, leadership, and project management.

- Sub-contracting and the extension of the supply chain will be a key factor with both international and domestic dimensions. Many functions such as cleaning and catering, as well as higher level activities such as research and development and design have already been hived off from the mainstream activities of many producers. This has accelerated the decline of employment in sectors such as manufacturing, while contributing to the growth of many parts of the service sector. Specifically for engineering companies devolved responsibility for technical design and development will continue and smaller organisations will need to develop enhanced skills and provide adequate resources.

- Reduced product life-cycles will require advanced planning and design methodologies which allow for customised, high value added products to be developed in a shorter period of time.

- Environmental sustainability and life-cycle analysis will become more important in meeting specific customer requirements, the requirements of new legislation and the acceptance of society generally.

- Service provision will become a key factor in business success. Companies will be judged on total service provision for all pre and post-production activities.

- Compliance with developing legislation is also expected to be another key area for companies across all sectors of engineering but especially those in higher technology areas. New environmental legislation is expected to present particular challenges to which companies will need to allocate sufficient resources. With regard to these issues the research therefore identified the need for the following skills: life-cycle and end-of-life management, design skills for sustainable manufacturing, risk assessment and contingency management and the ability to capture, understand and react to new and developing legislative requirements. It is understood that by anticipating and embracing environmental concerns organisations may gain competitive advantage through reconfiguring products to minimise environmental damage both in terms of reducing their own processing costs but also in terms of addressing customer concerns on environmental issues.

4.1.3 Occupational drivers.

As identified in chapter 4.1.2 occupational profiles are being significantly influenced by technological factors. In particular it was highlighted that the application of information technology and improved process automation techniques has led to the displacement of many skilled workers as their jobs have been taken over by computer controlled machinery, robots and other forms of automated equipment. On the other hand, information technology has created a number of new occupations particularly of a professional, associate professional and managerial nature through the growth of the pre and after sales service provision.

Wilson (2000) concludes that trends in occupational profiles are consistent with technological and economic changes within the workplace, such as increased automation, the introduction of new technologies, changes in trade patterns, competition from low wage countries and changes within work organisation.

Other studies completed to investigate occupational changes have drawn similar conclusions. The *skills base survey* completed by the DfES (2004) for example forecasted anticipated changes in occupational profiles for the whole economy through to 2010, see table 4(iv). Significantly, this survey highlights the anticipated trend to higher level managerial, technical and professional occupations and the decline of the skilled trades and operator categories. Specifically for the engineering sector it was forecast that this trend will continue through to the end of the decade. Craft trades and process, plant and machine operatives being most adversely affected.

	1971	1981	1991	1999	2010
Total employment (millions)	**24.4**	**24.5**	**26**	**27.5**	**29.7**
Managers and senior officials (%)	11	10	13	13	13
Professional occupations (%)	7	8	9	11	13
Associate professional / technical (%)	9	9	11	12	14
Administrative, clerical and secretarial occupations (%)	14	16	16	15	14
Skilled trades (%)	19	17	15	14	12
Personal service occupations (%)	3	4	5	6	8
Sales and customer service (%)	5	6	6	7	7
Process, plant and machine operatives (%)	14	12	10	9	8
Elementary occupations (%)	17	18	15	14	12
All occupations (%)	100	100	100	100	100

Table 4(iv) Occupational employment levels (1971- 2010).
Source : DfES (2004)

A trend towards higher-level skills is likely to impact on education attainment levels and it is expected that a greater number of graduates and people attaining intermediate technical qualifications will be required (Leitch, 2006). In terms of educational provision the requirement for higher professional and technical occupations will result in increased emphasis on qualifications such as Degrees, Higher National Diplomas (HNDs), Higher National Certificates (HNCs) and Foundation Degrees. Evidence for this assumption is provided by The *Office of National Statistics*, *Labour Force Survey* (2002) which established projections for occupational groupings within engineering through to 2009, see table 4(v).

Occupation	1998 level (000's)	2009 level (000's)	Change 1988-2009 (000's)	% change p.a
Engineering professionals	449	564	115	2.1
Engineering Technicians	207	498	-9	-0.4
Metal forming and welding trades	215	169	-46	-2.2
Machining and fitting trades	463	363	-101	-2.2
Assemblers and operators	597	594	-3	0.0
Plant and machine operators	334	271	-63	-1.7

Table 4(v) Occupation projections within engineering (to 2009).
Source: ONS (2002)

Despite the reduction in demand for foundation and intermediate level awards it is anticipated that the Modern Apprenticeship (MA) scheme will continue to contribute significantly to post-16 education (SEMTA) (2003). This conclusion is supported by reports such as the *Skills Foresight* (EMTA) (2000) and *Bridging the Continental Divide* (EEF)(2003) both of which identified that the performance of many engineering companies is being adversely affected by severe skills shortages at the craft and intermediate levels.

Some studies have however demonstrated that the UK engineering industry has lower skills on average than many of its major competitors - particularly for those people educated to intermediate and lower levels (Leitch,2006)(OECD, 2006). This situation is illustrated by that fact that Germany has 68% of its manufacturing workforce employed with intermediate qualifications compared to only 25% within UK manufacturing NIESR (2003), see figure 4.3. Specifically within Wales this problem has also been highlighted with the *Future Skills Wales Generic Skills Survey* (2003) stating that continued skill shortages have been experienced within specific areas such as the use of Computer Aided Manufacture, Computer Numerical Control, skilled machine operators and electrical maintenance. These shortages again reflect on the more generalized issue of recruitment difficulties at the intermediate and craft levels and the issue of inadequate skills is therefore critical in undermining the competitiveness of many UK engineering organisations. This situation appears to have been exacerbated by the relative demise of the traditional craft apprenticeship the low levels of on-the-job training in many companies.

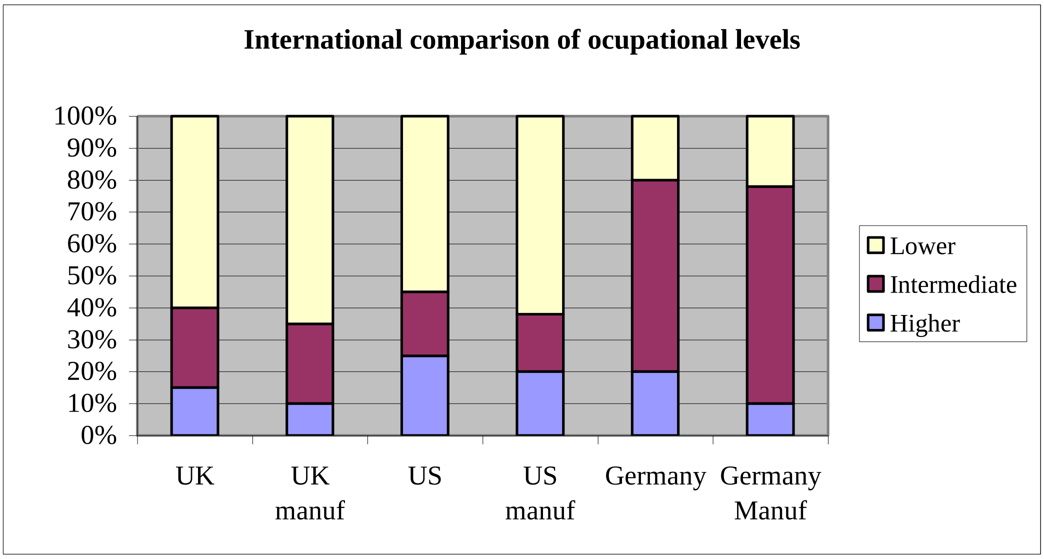

Figure 4.3 International comparison of occupational levels.
Source: National Institute of Economic and Social Research cited in The Governments Manufacturing strategy 2003, p.40

These studies illustrate that the provision of skills will need to be reviewed and in particular companies will need to develop or attract people with appropriate vocational, occupational and generic skills to satisfy a newly defined business strategy. Specifically, it is anticipated that the technical nature of engineering will require employees in all engineering occupations to acquire an appropriate level of numeracy and literacy. Evidence of the importance of generic skills is found in the *Work skills in Britain Report*, which concluded that the demand for generic skills from 1997 – 2010 will increase (Felstead, et al., 2002). Again in relation to Wales, similar conclusions were reached by *Future Skills Wales Generic Skills Survey* (2003), which indicated the increasing importance of generic and vocational skills required over a cross-section of engineering organisations in Wales. Similarly, the use of Information Technology and other computer systems is widespread and is set to continue and although the level of computer literacy required does vary across different engineering sub-sectors, in some cases the level of competence required may be very high. Thus, correlated to increasing technical innovation, an improvement in the levels of IT skills would also appear to be required. At operator level for instance the improved use of basic keyboard skills, simple word processing or spreadsheet packages would appear to be appropriate. At higher occupational levels however there will be the need to master computerised technology, which could be used for project planning, design or process control.

Managers will need to control occupational changes by anticipating the effects on customers and employees. In this respect in the short-term the trend towards flatter hierarchical structures is likely to continue and in the longer-term companies will need to evolve a more integrated organisational architecture (*UK Government, Foresight* - *Ways of Working,* 2003). In light of the increasing importance of knowledge-based production companies should consider organising around intellectual capital and not physical machinery. Matrix structures which are dynamic in responding to a changing market may therefore be increasingly utilised. Any increased use of matrix structures will continue the trend towards reducing the number of job titles and an increase in cross-functional support. In an effort to attain flexible and lean production the anticipated shift towards customised and high value-added production will also force many companies to adopt a bottom up approach as opposed to the traditional top-down structure. The widespread use of team working and cellular manufacturing is therefore set to increase through the use of multi-skilled teams. In the case of higher qualified occupations and professions, employees will need greater networking and communication skills as well as team management ability. Greater emphasis may also be placed on part-time and shift working as companies strive to increase flexibility and reduce costs.

The occupational challenges facing UK engineering are compounded by demographic problems as well as social and legislative pressures. An issue which has affected the competitiveness of many UK engineering firms is the ageing nature of the workforce (Leitch, 2006). The average age of engineering workforce was also found to be heavily dependant on the sub-sector under consideration. EMTA (2004) investigated this issue and completed an analysis of the general engineering workforce which confirmed that 15% of the engineering workforce to be between 16 and 24 years of age, and 35% to be aged 45 years or older. However, the electronics industry had a younger workforce than the national average whilst the traditional mechanical industries tended to have higher proportion of workers in the 30-39 year old age group. Thus, the age distribution in specific sub-sectors will need to be considered to avoid recruitment and training issues (particularly for those sub-sectors where many individuals are close to the retirement age). In some sectors of the engineering industry the total replacement demand is forecast to outweigh the general contraction in each occupational group and lead to an overall net requirement SEMTA (2006). Furthermore SEMTA concluded that there is likely to be little change in the pattern of engineering employment within the UK and it is therefore expected that the workforce will remain predominantly male, in full-time employment with relatively few self-employed people.

Social and legislative pressures may for example, force organisations to consider a more family friendly working environment with greater flexibility in working hours. Any increase in the mobility of workers is likely to threaten company development and organisations will need to identify key individuals with core competencies complementary to the business plan. These individuals will need to be prized, rewarded and developed accordingly. Again with the increased mobility of labour, organisations will need to recognise the vitally important role of induction training and look to bring employees to the point where they are adding value in as short a period as possible.

In conclusion, it is expected that occupational changes will reflect and be consistent with the economic and technological drivers previously identified. Significant implications for occupational profiles are therefore forecast to include the increased importance of activities involving commercial awareness, customer service, supplier integration, information handling and exploitation, process control, communications, the building of relationships and the exploitation of technology within the various stages of production cycle.

The trend to increasing managerial and engineering complexity will impact on the number of people employed in managerial, professional, technical and customer service roles. Conversely, it was forecast that the number of people employed within skilled trades, processing and plant / machine operations will fall. The trend towards higher occupation and managerial levels is likely to impact on the requirement for higher educational attainment, particularly at the higher and intermediate levels. It is therefore concerning that research has identified that an inadequate proportion of UK workers are educated to higher and intermediate levels. Specifically with regard to this thesis the shortfall at intermediate level is of particular interest and qualifications at this level include Technical Certificates such as the National Certificate - which are required for the completion of Modern Apprenticeships, National Diplomas, Higher National Certificates, National Vocational Qualifications (NVQs) at levels 2 and 3 and GCE A levels. The deficit is most clearly demonstrated in the comparison between the UK and Germany (where nearly three times the number of manufacturing sector workers are educated to intermediate level). In light of this shortfall it is significant that several studies have concluded that the performance of many organisations will continue to be undermined by skill shortages at the intermediate level.

The issue of low numbers of employees educated to intermediate level is compounded by the findings from research on demographic trends which highlights the aging nature of the engineering workforce and therefore that recruitment demand is likely to be high as existing workers retire or make career changes. Several studies highlighted the increasing trend to supplement higher levels of occupational profiles / skills with acquisition of broader and deeper generic skills. It is possible that that within some occupations the importance of gaining and exploiting these generic skills could be at least as important or even more important than the acquisition and exploitation of appropriate technical or occupational skills. It is however significant to note that the generic skills highlighted as important are generally complementary to those technical and occupation skills previously identified.

Finally, to facilitate increased effectiveness it is anticipated that the trend towards flatter organisational structures will continue with many organisations (particularly those operating within the higher technological sectors) choosing to define their organisation in terms of intellectual capital rather than physical capital. These organisations must be designed to be open and agile and allow employees to utilise the generic, occupational and technical skills they have acquired.

Summarising, issues for consideration within the final curriculum proposal have been identified as following:

- How to develop open, agile, motivational organisational structure.
- Skills development and continued professional development.
- Acquisition of appropriate vocational, occupational and generic skills.
- Redefining roles and functions.
- Career changes.
- Workforce demographics and changes in occupational demand.

- Development of a learning culture.
- Encouraging the gathering of intellectual capital.

4.2 Characteristics of world-class engineering industry.

It is helpful in terms of this thesis to augment forecasted economic, technological and occupational changes by identifying a set of characteristics, which describe world-class companies. *The Winning Report* (2003) - a study of the UK's most successful companies, conducted by the Confederation of British Industry and the Department for Trade and Industry (DTI) identified the following characteristics, which distinguished world-class organisations from the remainder of their sector:

- They have strong leaders, who champion change, set targets and are open with customers, staff, investors and suppliers.
- They unlock the potential of people by simplifying management, developing skills and encouraging working in teams.
- They constantly learn from others.
- They are innovative, continuously seeking to introduce new products and services by exploiting new technology and other ways of securing a competitive edge.
- They anticipate customer requirements and consistently exceed customer expectations.

The study demonstrates that successful firms exploit the inter-relationships between these areas by empowering and training employees. Subsequently, the report also identifies a range of key issues which were considered of significance in terms of gaining competitiveness and performance as follows: company organisational culture, lean production, logistics, total quality, e-business, concurrent engineering, manufacturing and engineering systems, innovation and product development and environmental management and health and safety management. These conclusions are generally consistent with the findings of the research detailed in chapters 4.1.1 to 4.1.3 of this thesis. Combining all information it was possible to complete a generalised Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for UK engineering industry (see fig 4.4). It is important to note that the analysis is not intended to be applicable to all companies regardless of size, sector, customer base etc, but rather it is a generic list of characteristics for the UK engineering industry.

Strengths

Economic

- Modern economy with a significant history of industrial activity
- Political stability
- Stable economic outlook
- Low inflationary pressure
- Good economic growth forecast
- Significant inward investment
- Relatively low taxation costs
- Relatively low utility costs
- Exchange rates can be manipulated by governmental monetary policies
- Relatively low interest rates
- Highly developed venture capital industry

Technological

- Integrated supply network
- High level of compliance with legislation
- Excellent communications infrastructure
- Good IT/internet connection rates
- High tech sectors such as defence, pharmaceuticals and aerospace are strong in comparison to competitors
- Establish quality systems culture
- Highly developed technical standards industry
- High-tech clusters developed
- Major restructuring of labour intensive industries already completed
- Large number of smaller companies allows for flexibility of production
- World class science and research base
- Established engineering institutions and bodies

Occupational

- Well Established HE / FE system
- Well establish compulsory schooling system
- Well established apprenticeship frameworks
- High financial rewards available
- Flexibility of labour is high
- Established engineering institutions
- Educational attainment valued highly

Weaknesses

Economic

- Comparatively low number of large, world-class companies
- Additional exchange rate costs
- Fluctuations in exchange rates
- Difficultly in planning ahead due to uncertainty of exchange rate
- Low level of entrepreneurship compared to competitors
- Excessive consideration given to short payback periods as opposed to ROCE
- Venture capital for financing engineering not always readily available
- Engineering activities often considered to be peripheral to the economy
- No coherent strategic consideration given to reversing decline in engineering
- Interest rate fluctuation prevents capital investment over long term

Technological

- Significant burden of H&S, environmental and social legislation
- Comparatively low productivity levels
- Low R and D investment compared to major competitors
- Low number of companies involved in the high R and D sectors
- Low utilisation rate of new technologies
- Raw materials often imported and therefore subject to price volatility
- Insufficient capital investment levels
- Patent realisation is low compared to competitor countries
- Links between research establishments and industry need further strengthening
- Many engineering companies are operating in antiquated premises which do lend themselves to further technological development

Occupational

- Comparatively low educational attainment to competitors, especially at lower and intermediate levels
- Low vocational and generic skills base
- Low uptake of engineering courses
- Low interest in engineering from women
- Low generic skills level
- Stocks of specific skills are low
- Poor image of engineering
- Aging workforce within many engineering sectors
- Recruitment difficulties leading to shortage in specific areas of expertise

Figure 4.4 SWOT analysis.

Opportunities	Threats
Economic • Euro zone membership • Improve interface between education and industry to better exploit innovation • Continued promotion of open market policies • Expansion into Eastern European markets • Political stability can be exploited to enhance inward investment • Favourable economic conditions can be exploited to enhance inward investment • Governmental incentives to promote expenditure of venture capital **Technological** • Relocation of manufacturing sites for price sensitive products • Supply chain agreements/ partnerships / Outsourcing arrangements • Customisation of products • Use of advanced materials, process and energy sources to satisfy customer demands • Use of cleaner energy sources • Development of environmentally friendly products • Restructure technical departments to allow for localised customer support • Devolve greater technical responsibility to suppliers • Use of advanced computer modelling and design packages to shorten lead time to market • Place added value and service provision at centre of the organisation • Greater use of e-commerce • Utilisation of new technologies such as biotechnology • Increased innovation through patent generation and subsequent development **Occupational** • Recruitment from a wider cross section of the population • High replacement demand will allow for a re-education opportunity • Increased use of apprenticeships to augment intermediate level qualifications • Expand to incorporate service provision into mainstream activities • Harness diversity of supply • Increased provision of governmental financial inventive to promote education involvement and address specific skills shortages	**Economic** • Competition from low cost economies • Globalisation of supply • Conservatism in investment, innovation etc • Currency transaction costs undermine competitiveness • Transfer of production to low cost centres • Governmental policy to euro zone membership may prevent further inward investment into the UK • US protectionist policies affecting specific sectors • Financial institutions demanding excessive returns on investment **Technological** • Technology gap between UK and the third world is closing • Ubiquitous nature of information • Inadequate awareness of technology and science • Educational establishments not sufficiently commercially aware • Poor rate of patent generation will undermine innovation • Low productivity rate • Under investment in capital expenditure • Continued low development of patents **Occupational** • Inappropriate education curricula • Aging workforce in manufacturing sector • Mobility of workforce • Threats of recruitment from other economic sectors • Poor generic skills • Poor rate of apprentice training undermining intermediate and craft levels • Poor image of engineering • Many other economic sectors perceived to provide for better remuneration and working conditions • Lack of a clearly defined career structure undermines recruitment of the most able students into engineering • Poor numeracy and literacy of many students recruited into engineering industry

Figure 4.4 SWOT analysis.

The SWOT analysis although useful does not take into account the diverse nature of the UK engineering sector and it is noted that what is applicable in some industries would not necessarily be important in others. For example, superiority in technical innovation or research and development is important to companies involved with technically complex products but not for companies involved in mass production of commodity items where price and cost sensitivity is of far greater importance. The Warwick Manufacturing Group has refined these characteristics by using the "Puttick Grid" (Puttick, as cited in Bonser et, al., 1995). The technique allows for companies to be classified as being involved in the production of products either of high or low complexity and in a market of either high or low uncertainty. Companies involved in the production of high value-added products in an uncertain market occupy the top left quadrant of the grid (e.g. production of aircraft manufacture). Companies involved in the production of products with short product life-cycles and low product complexity within an uncertain marketplace occupy the top right quadrant (e.g. production of fashion items). Companies involved in the production of technical demanding products which are well-established within a longer life-cycle occupy the bottom left quadrant (e.g. production of automobiles). Finally, companies involved in the production of durable goods having very long life-cycles and low complexity, occupy the bottom right quadrant (e.g. production of light bulbs).

Referenced against the OECD definitions for manufacturing industry (chapter 4.1) it was possible to locate the previously defined engineering sub-sectors against each quadrant of the Puttick grid, (see figure 4.5). In relation to this thesis the importance of the Puttick grid lies with the fact that a complementary skills profile can be obtained for companies operating in each quadrant. As an example of how this can be achieved a tentative list of what can be considered to be the appropriate skills for each quadrant has been constructed, see figure 4.6.

Taking into account the completed SWOT analysis a summary of the salient economic, technological and occupational divers (both internal factors and external constraints as identified in the literature study) was established, see table 4(vi).

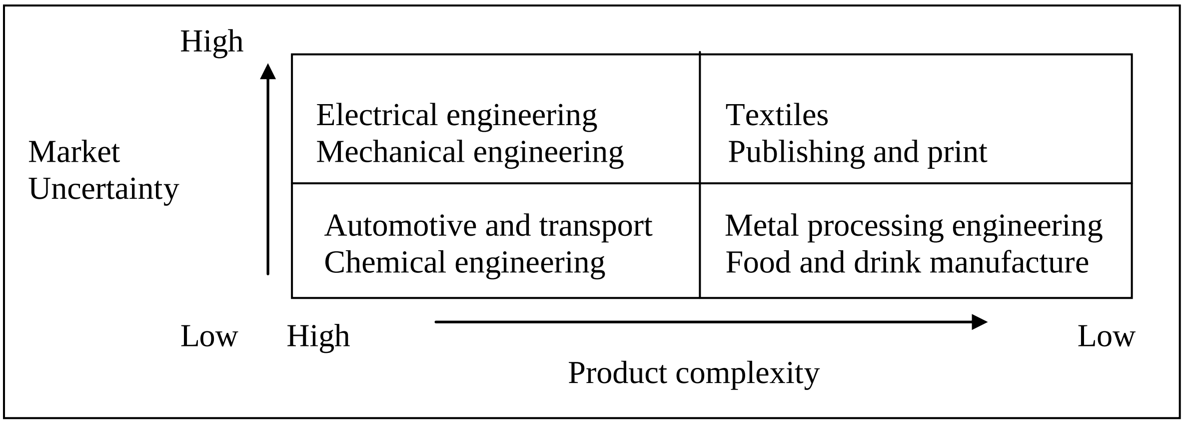

Figure 4.5 The Puttick Grid.

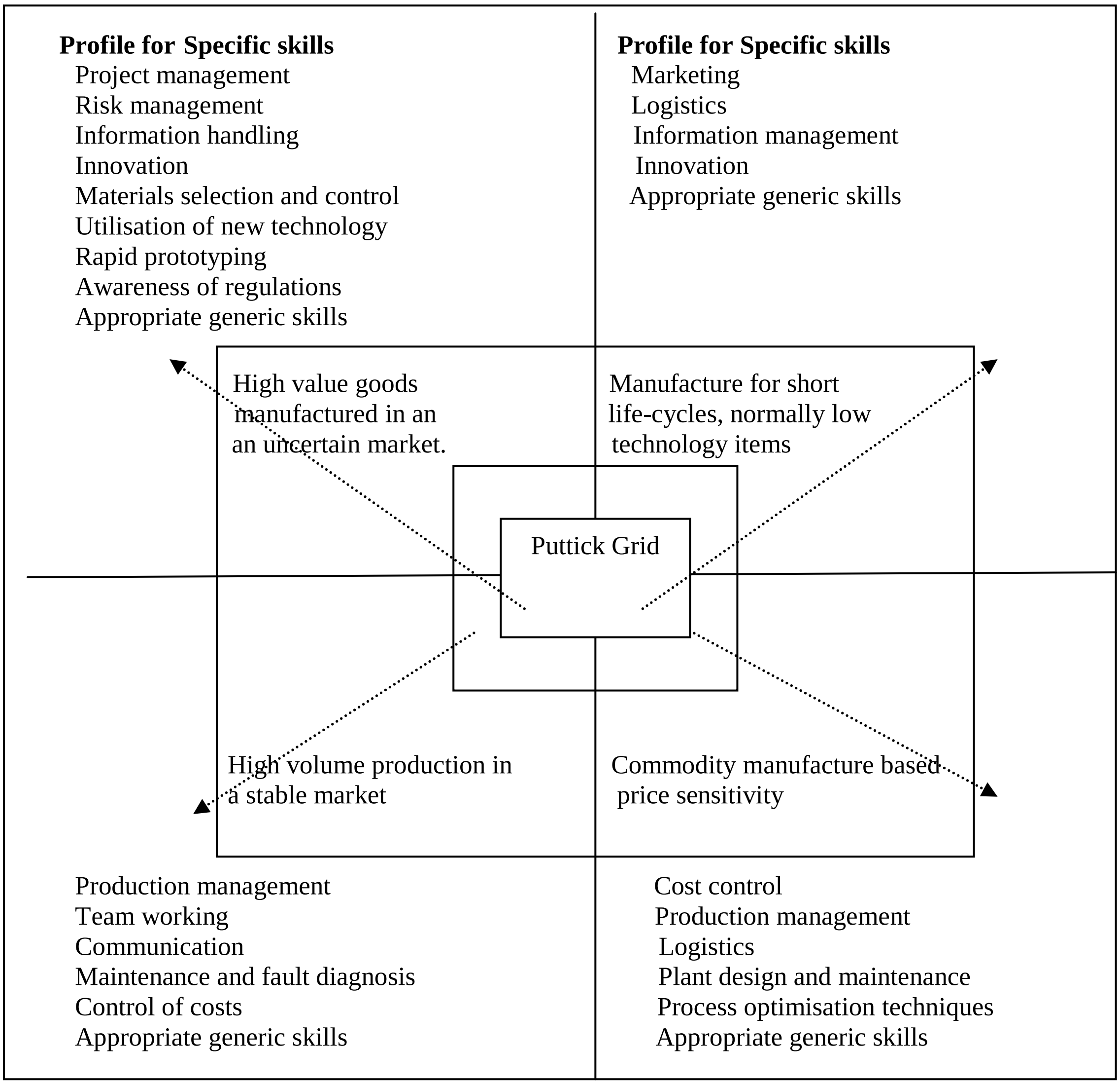

Figure 4.6 An example of how a specific skills profile can be established.

Economic drivers

Internal factors	External constraints
Sensitivity to exchange rate changes	Fluctuations in the exchange rate
Sensitivity to interest rate changes	Fluctuations in the interest rate
Sensitivity to inflation rate changes	Fluctuations in the inflation rate
Sensitivity to taxation rate changes	Fluctuations in taxation rates
Labour costs	Utility costs
Materials sourcing policies	Raw material costs

Overhead costs	Governmental monetary policy
Supplier selection	Potential membership of the Euro zone
Return on investment policy	Level of inward investment
Acquisition policy	Level of governmental support
Pricing policy	Political stability
Level of marketing / marketing policy	Level of regulation/ changes in regulation
Level of capital investment	Sector decline
Location of production	Location of sales
Level of financial planning and control	Level of economic activity
Returns to investors	Venture capital availability
Strategic business planning	Tariffs
Level of borrowing	Banking costs/ borrowing costs
Customer support polices	Exports dependant on foreign economic conditions

Technological drivers

Internal factors	**External constraints**
Level of R and D investment	Globalisation effect – customisation of supply
Level of supply chain integration	Globalisation effect – ubiquitous information
Level of patent generation	Globalisation effect – ubiquitous technology

Productivity levels	Environmental issues
Exploitation of new materials/processes	Sustainable development
Development of new products	Exploitation of new materials/processes by competitors
Exploitation of new energy sources	Development of new products by competitors
Design policy	Exploitation of new energy sources by competitors
Outsourcing policy	Effect of legislation
e-commerce / IT exploitation	Social acceptability of product/ process - Locally / globally - Shareholder / stakeholders
Quality of supply / design / production	Infrastructure – transport
Production strategy	Infrastructure - communications
Maintenance strategy	Life cycle costs
Lead times/ delivery times	Customer requirements customisation V cost
Commitment of continuous improvement and lean manufacturing	Speed of supply
Production alliances	Pace of technological change
Level of diversification	
Knowledge capture mechanisms	

Occupational drivers

Internal factors	External constraints
Recruitment policy	Competition for recruitment
Remuneration policy	Demographic changes – image issues
Education and training policy	Demographic changes – age of workforce
Occupational balance	Demographic changes – recruitment of females
Organisational structure	Demographic changes – labour availability
Management polices / corporate style	Changes in workforce patterns
Work patterns	Poor image of vocational education
Partnerships with educational institutions	Poor basic & key skill attainment of recruits
Trade union policy	Skill shortages in specific areas
Interdisciplinary / mutli-skilling	Governmental policy on education
Recruitment of apprentices	Educational institutions – curriculum design
Skills required – generic	Recruitment levels in F/T education
Recruitment and retention of core workers	Governmental funding policies
Multi-cultural polices	Multi cultural issues
Skills required – technical	Barriers to learning
Skills required – information handling	Retention and attainment levels in education
Skills required – generic	

Skills required – professional and business	

Table 4(vi) Salient economic, technological and occupational drivers.

4.3 Chapter summary.

A chronological review has been completed and a historical perspective of the engineering industry and forecasted future scenarios established. Salient economic, technological and occupational drivers of change likely to impact on manufacturing engineering have been identified. Findings were supplemented by data gathered concerning the characteristics of world-class engineering companies as well a SWOT analysis completed for the UK engineering industry.

The output of this chapter is a comprehensive listing of the salient economic, technological and occupational drivers which will affect UK engineering companies in the future. The challenge to UK engineering companies is to establish a model of operation having a complementary skills profile which will be sufficiently robust to the any possible future scenario and suit the nature of the market the companies operates within.

CHAPTER 5

IMPLEMENTATION - LEARNING THEORY AND RELATED CURRICULUM PLANNING ISSUES

This chapter has two purposes.

Firstly, in recognition of the need to develop the final curriculum proposal in a complementary manner to the requirements of the engineering students this chapter is used to explore elements of learning theory and related curriculum planning issues. Initially, an introduction to curriculum characteristics and learning theory is considered. Subsequently, the domains of learning and the main perspectives on learning are explored and evaluated with related matters concerning student learning styles and assessment methods also investigated. The output of this work is to identify appropriate curriculum characteristics for incorporation into the final curriculum proposal. In particular complementary learning, teaching and assessment methods and course management features are identified - which are philosophically consistent with the purpose and context of learning within this thesis.

Secondly, to allow for an evaluation of the effectiveness of existing engineering educational provision (in comparison against the final curriculum proposal) this chapter is used to investigate a range of awards (within the 16-18 year age group in Wales).

5.1 Introduction to curriculum characteristics.

Socio-philosophical concepts concerned with curriculum design were discussed in chapter 2.2 and it was identified that post-compulsory education is generally accepted to involve attempts to raise economic performance. In this context the most appropriate definition of the curriculum would be through a technological orientation (where the aim is to achieve pre-specified ends). By describing and managing education as a product for delivery, the design of a curriculum can be said to be concerned with specifying the objectives of learning and in turn the subject matter to be taught and learned. Clearly, the philosophical perspective of the purpose of education itself will have a fundamental impact on this process and in the context of this thesis the synergy of TQM, competency-based and progressive approaches to curriculum design has already been hypothesised in relation to industrial performance. However, a number of issues relating to the practicalities of curriculum design have already been highlighted. Firstly, is often unclear how learning outcomes are established and there is a requirement for the principled and theoretical justification for the selection and interrelationship of learning outcomes. Secondly, curriculum features are more defensible if the learning outcomes are reflective of the requirements of the client groups (established and owned by the students and employers). In recognition of the need to develop the final curriculum proposal in a complementary and sensitive manner a pragmatic approach to curriculum content which is reflective and deliberative is required. This approach should provide assistance at arriving at sound practical judgments concerning the selection of course content and of teaching and assessment methods.

Regardless of the ideological orientation of the curriculum, a series of generic characteristics or elements within the curriculum can be identified. Walker (1990) argues that the characteristics of a curriculum should include content, purpose and organisation. This highlights a philosophical consideration of the purpose of the curriculum and the effect of learning theory. Beane, et al., (1986) offer similar but less generic characteristics of the curriculum, such as making decisions on content, teaching and learning methods and assessment methods. These definitions provide a reasonable scope for further investigation and it is proposed to investigate curriculum features in terms of learning theory, teaching and learning styles and assessment methods (note: content is addressed in chapters 4 and 6). Using the devised curriculum design method this chapter is therefore used to identify what are considered to be theoretically justifiable and complementary curriculum features. As described in chapter 3.2 in order to provide a consideration of the requirements of the students learning, teaching and assessment methods considered complementary will be subsequently tested (see chapter 7).

5.2 Introduction to learning theory.

Crow and Crow (1963) view learning as involving change and being concerned with the acquisition of habits, knowledge and attitudes to enable an individual to make personal and social adjustments. Gagné (1965) concurs by characterising learning as a retained change in

human capability. Gagné (1977) extends this further by observing that learning is dependent on the events or occurrences an individual student experiences and Gagné therefore establishes the applied nature of teaching as a practical science. Knowles (1998) provides guidance on the effective application of teaching (for the attainment of learning) by demonstrating a better understanding of learning theory will result in better decisions regarding learning experiences. Thus, it can be accepted that to construct a practical, meaningful and effective curriculum proposal it is necessary to understand the psychological aspects of learning theory. In particular, within the context of this thesis an understanding of learning theory will aid in the decision making process to devise a final curriculum proposal which best satisfies the requirements of the students and employers.

5.2.1 Domains of learning.

Bloom (1956) in establishing the taxonomy of educational objectives provides a basis for classifying learning into domains and thus highlights learning outcomes should be hierarchical and concerned with different forms of learning. Reece and Walker (1998) state three main groups of learning termed the psychomotor, cognitive and affective domains. Petty (1998) states that the cognitive domain is concerned with knowledge and knowing, the psychomotor domain is concerned with physical skills and the affective domain concerns itself with attention, awareness, moral, aesthetic and other attitudes, opinions or values. Each domain learning behaviour is classified with a taxonomy (Bloom 1960), (Krathwohl et al., 1964) (Dave 1970).

Reece and Walker 1998, p. 66-68 provide clarification of each developed hierarchical taxonomy (see figures 5.1, 5.2 and 5.3). Reece and Walker (1998) demonstrate this understanding of the taxonomies will help in allowing for a practical understanding of the most appropriate learning outcomes (in relation to the student entry level), see tables 5(i), 5(ii) and 5(iii). Furthermore, an appreciation of the domains of learning is of practical importance since by identifying the domain(s) within which the learning to be undertaken is located, an appreciation of the most suitable teaching, learning and assessment methods can be gained. Gagné (1965) proposes an alternative but complementary approach in which two conditions (termed internal and external) are distinguished. Gagné describes internal conditions as including attention, motivation and recall. The external conditions are considered to be factors surrounding the behaviour of the learner and include factors such as stimulation by others and the extent to which tasks have meaning. Furthermore, Gagné identified five major categories of learning as being: verbal information; psychomotor skills; intellectual skills; cognitive skills and attitudes. The work of Gagné emphasises a desire that the internal and external conditions are identified to ensure the learning outcomes are achieved and that these outcomes themselves are defined in behavioural terms.

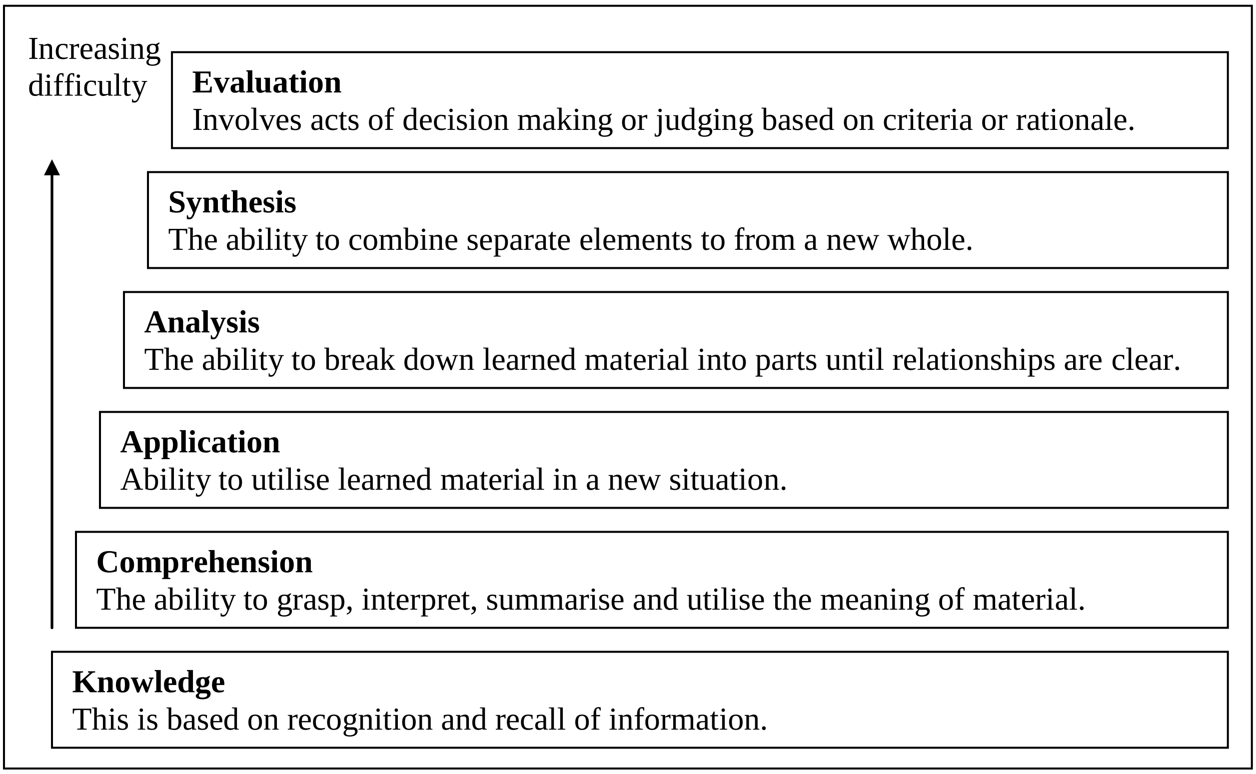

Fig 5.1 Cognitive hierarchy.

Source: Reece and Walker 1998, p. 66-68

Increasing difficulty ↑

Naturalisation.
Completes one or more skills with ease and becomes automatic.

Articulation
Combines one or more skills in sequence with harmony and consistency.

Precision
Reproduces a skill with accuracy, proportion and exactness usually performed independent of the original source.

Manipulation
Performs skill according to instruction rather than observation.

Imitation
Observes skill and tries to repeat it.

Fig 5.2 Psychomotor hierarchy.
Source: Reece and Walker 1998, p. 66-68

Increasing difficulty ↑

Characterising
Total behaviour consistent with internalised values.

Organising
Committed to a set of values as displayed by behaviour.

Valuing
Displays behaviour consistent with single belief or attitude.

Responding
Complies to given expectations by reacting to stimuli.

Receiving
Aware of passively attending certain stimuli for example listening, reading etc.

Fig 5.3 Affective hierarchy.
Source: Reece and Walker 1998, p. 66-68

Level	Teaching method	Objective
Evaluation	Work experience, simulation	Judge, appraise, justify
Synthesis	Problem solving, project	Design, combine, derive
Analysis	Discussion, assignment	Analyse, criticise discriminate
Application	Case study, role play	Demonstrate, use, perform
Comprehension	Seminar, tutorial	Explain, illustrate, identify
Knowledge	Lecture, TV, video	List, describe, state

Table 5(i) Cognitive hierarchy
Source: Reece and Walker (1998)

Level	Teaching method	Objective
Naturalisation	Real life experiences	Assemble, build, design
Articulation	Workshop	Combine, dismantle, correct
Precision	Practical, project	Operate, produce, construct
Manipulation	Resources, handouts	Use, perform, practice
Imitation	Demonstration	Watch, observe, copy

Table 5 (ii) Psychomotor hierarchy
Source: Reece and Walker (1998)

Level	Teaching method	Objective
Characterising	Real life experiences	Exhibit, display, act
Organising	Simulation	Combine, integrate
Valuing	Role play, games	Perform. study, share
Responding	Group work, case study	Comply, answer, practice
Receiving	Observation	Identify, follow

Table 5(iii) Affective hierarchy
Source: Reece and Walker (1998)

It has been shown that an important element of the work carried out by Bloom and Gagné is in their influence on the design of delivery as well as the selection of appropriate learning and assessment methods. These classifications demonstrate that different types of learning require different forms of teaching and learning and different internal and external conditions are necessary for learning to occur.

However, in relation to this thesis, a number of issues emerge which need further consideration. Firstly, there is the potential that one domain is over-emphasised at the expense of another. This may be the case in engineering for example where the psychomotor and cognitive domains may be assumed to have greater relevance than the affective domain. Conversely, there is potential that during the design of a curriculum proposal that in a desire to cover all domains the coverage of a key domain may be adversely affected. This issue was initially identified within chapter 2.5.1 and it was concluded that the construction of pre-determined outcomes reflecting on what engineering students are perceived to do is flawed. It was hypothesized that the implementation of the curriculum model within this thesis will overcome this issue since the curriculum details are obtained directly from the students and employers themselves and should therefore accurately reflect their actual requirements. Thus, generic domains of learning can be established which will accurately reflect the requirements of the client groups. In turn, specific abilities within each domain can also be established. Secondly, in relation to engineering education it is debatable if the semantics of the each recognised taxonomy is fully appropriate. Here it would appear to be advantageous to develop a semantic structure which is specifically relevant to engineering and the client groups concerned with the actual delivery. It is anticipated that this issue can be addressed by again employing careful consultation with client groups.

Nevertheless, Bloom's work does appear to be analogous to a checklist approach and so complementary to the context of this study in which ensuring adequate provision is planned to deliver the necessary development of students is achieved primarily through the use of TQM techniques. Use of Bloom's taxonomy therefore allows for the opportunity to design a programme of study which is built on previous knowledge and skills and that these skills are identified and described as a perquisite for the learning objective. Since the curriculum being developed is for the education of 16-18 years olds it may be assumed that a reasonable correlation is to the first three levels within each of the taxonomies and this will be included within each curriculum matrix (see chapter 8.3).

5.3 Perspectives of learning.

To ensure the construction of an effective curriculum proposal an understanding of the psychological aspects of learning has been established to be of clear importance. Reece and Walker (2003) identify the main perspectives of learning as behaviourism, neo- behaviourism, cognitivism, humanism and constructivism. Each are now considered in turn.

5.3.1 Behaviourism.

Curzon (1997) defines the basic assumption of behaviourism as that all behaviour can be explained in terms of physical responses to external stimulation. As a result behaviourists consider that a physical observation or measurement is required to prove learning. Theorists associated with this school (such as Pavlov and Thorndike) view that learner behaviour is controlled or changed as a result of the application of stimuli under controlled conditions.

There has however been criticism of behaviourism which appears to be well founded. One criticism centres on the ability of behaviourism to extrapolate results obtained within the laboratories (which were often conducted on animals) to that expected with humans (Reece and Walker, 2003). Curzon (1997) by criticising behaviourism as a process of conditioning close to brain washing views the use of these methods as incompatible with the freedoms normally associated with the classroom. Proponents of behaviourism however identify its widespread use within education of rewards and punishments to control behaviour and learning and how positive reinforcement methods can help in the learning process (Rogers 2002). Despite concerns over the extent to which behaviourism can be and should be adopted in a classroom environment practical applications in the establishment of learning outcomes, testing methods, reinforcement or the acquisition of practical skills are evident in current-day practice. This viewpoint highlights how a behaviourist model affects cognitive development, assessment and motivation. Thus, in accepting the behaviourist model recognition of external motivation and hierarchal learning must be made. This is highly questionable and appears incompatible with the aims of this thesis and these issues are considered further in chapters 5.3.2 to 5.3.5.

5.3.2 Neo-Behaviourism.

The work of behaviourists was extended by the neo-behaviourists in applying a more human approach to learning and attempting to further consider the role of the mind in learning (Curzon, 1997). Skinner (1935) demonstrates this through the introduction of the concepts of operant conditioning (voluntary responses) and reinforcement. Gagné (cited in Curzon, 1997) concluded that the learning methods had to be designed to match the type of learning taking place. A more holistic view of learning is evident which identifies the importance of learner beliefs and expectations as well as the role of the teacher in setting the right conditions of learning to suit the need of the learner and the type of learning to be undertaken.

5.3.3 Cognitivism.

Bower and Hilgrad (cited in Curzon, 1997) define cognitive psychology as concerned with how organisms gain knowledge about their world and how they use that knowledge to guide decisions and perform actions. The cognitivism model therefore emphasizes the role of the mind in learning rather than physical responses (as required by the behaviourists). The importance of cognitivism is that it implies that learning is an active process which involves the learner taking responsibility and that the teacher should select activities appropriate to the level of learning being undertaken. The cognitivism model of learning therefore recognises the learner as being an active participant in the process who interacts with the teacher and the learning environment. This internal process differs significantly from the external stimuli required by behaviourists and displays how individuals gain the ability to learn themselves through metacognition.

Dewey (1933) identified that metacognition should extend to the area of vocational education and warned against merely training people to perform manual tasks, this is of clear relevance to this thesis. Furthermore, Dewey identified the importance of ensuring that learning tasks are not disassociated from a social context and should become meaningful to the learner. Here a divergence from the approach proposed by behaviourists is particularly evident. In the vocational context of engineering education Dewey therefore highlights the need to ensure students are not merely trained to perform tasks but educated and developed.

Bruner (cited in Entwhistle, 1987) concurs that learning is not just the acquisition of knowledge but the means to develop individuals and highlights educational concepts such as discovery thinking where students are taught how to analyse problems and solve them independently. Bruner (1967) again views learning as a process rather that some defined output. Thus, problem solving situations where the learner draws on his or her own past experience and existing knowledge to discover facts and relationships are emphasised and here a constructivist learning theory is also evident. Further similarities between cognitivists and constructivists can bee seen by accepting that learners understanding is built through a complex network of schema (mental structures) in which the role of memory provides a means of understanding (Bartlett, 1932).

Further practicalities in delivery are offered by Ausubel (cited in Curzon, 1997) who advocates that learning is best achieved through reception learning in which learners are presented with materials delivered in a methodical and sequential manner and with information placed in context. This again demonstrates that the responsibility for learning is still retained by the learner. It is however highly debatable if an overly prescriptive and sequential approach would best suit all learners. Here a contradiction to the Gestalt and humanism approach is evident where facilitation and the role of motivation and emotion are more fully considered. Ausubel specifically proposes the use of advance organisers to prepare students and anchor knowledge. In practice this technique can be used for recapping on materials at the start of a lesson, summarising material at the end of a lesson, sequential planning via a scheme of work, consolidation, practice and reviewing of information. These theories point to the active engagement of the mind in relation to the work being studied. The process of creating responses is seen as more important than the response itself and therefore clearly different to the behaviourist outlook.

Summarizing the cognitive approach it provides a more holistic approach to learning. In comparison to behaviourist theory the process of learning is stressed rather than just the outcome of learning. The cognitive approach recognises the importance of prior experience and knowledge where the learner becomes an active participant in the learning process and in his/ her own personal growth. These factors have already been identified as desirable within this thesis. Possible criticisms identified include an overdependence on a sequential model of learning and a general recognition that the cognitive model does not sufficiently recognise the importance of emotion in the learning process.

An important development of cognitivism is provided by the Gestalt (pattern) theory. Koffka (1955) illustrates this development by concluding that learning can not be reduced to a sequence of thoughts in a structure manner and learning is viewed as more of a creative process involving perception. Thus, Gestaltists believe that learning can not be achieved in some pre-determined manner, rather it must allow for the creativity of individuals and their different thought processes. Gestaltists acknowledge that learning is influenced by attitudes, past experiences, emotion and intellect and that learning is not a continuous process but rather it occurs as a sudden experience often through some intuition or inspiration. In use the Gestalt theory therefore places a heavy emphasis on the context in learning and within engineering education this would be of clear benefit. However, a disadvantage with the Gestalt theory must be the recognition that not all learning is suited to problem solving techniques and in some cases information needs to be acquired by rote. It can be argued that experience is not sufficiently considered and that success in problem solving can occur as a result of this prior knowledge. It is clear however that Gestalt theory is particularly suited to applications where creative thought and transferable cognitive skills are being developed particularly at higher levels. Examples for use would include the use of faultfinding exercises for engineering equipment and here applications within this thesis are evident.

5.3.4 Humanism.

The humanist perspective of learning places emphasis on the relationship between the teacher and the student (Petty, 1998). Humanists consider that learning occurs when the facilitator (instead of teacher) and the student engage in an atmosphere of trust and empathy (Armitage, et al., 2002). A humanistic perspective acknowledges the cognitive theories of learning but views that humans as individuals are free to decide on their own course of action and therefore are responsible for their own learning.

Maslow (1943) in making a significant contribution to humanist theory established the Hierarchy of Human Needs which is related to the motivation of students. Maslow concluded that gratification of needs at the lowest level of the hierarchy allows a person to seek gratification at a higher level, which ultimately results in self-actualisation. In developing this theory Maslow demonstrates the role of motivation affects the personal growth and development of the learner and reminds the tutor that within any group of learners there will be a wide variety of needs. Marton and Säljö (cited in Duff 2000) also consider motivation and describe student motivation to learning as a surface or a deep approach. Within the surface approach the motivation is extrinsic (carried out because of either positively or negatively reinforced consequences). The deep approach is based on intrinsic motivation and there is a personal commitment from the student to learning. This is an interesting point within the context of this thesis since many engineering students are undertaking educational courses in response to employer instructions. Thus, levels of personal commitment may vary within each group.

Tennant (1997) considers this issue further by viewing many of the factors affecting learning as outside the control of the teacher but contends that the mission of the teacher should be to provide help to individuals to allow for gratification at whatever level of the hierarchy students are attempting to achieve. Gibbs (1992) also highlights how the conditions set by the teacher have an effect on learning by associating surface learning with a heavy workload, a lack of student choice over the teaching methods adopted and excessive course material. A deep approach to learning in turn being associated with learning by doing, student reflection, problem-based learning, independent learning and allowing the students participate in the choice of teaching methods.

Rogers (1967) developed the complementary concept of facilitation and again demonstrates in the humanist perspective of learning the importance of putting the learner at the heart of the learning experience and encourages a shift from direct learning to one of facilitating a process of learning how to learn. Rogers also criticized traditional methods of learning such as lecturing all students to a prescribed curriculum and standard assessment methods and instead identifies alternative methods of learning such as the compatible concept of student-centred learning. It must however be debatable if this is a practical proposition within engineering education where limitations in the availability of resources are an issue.

Knowles (1984) extended the humanist perspective of learning by producing the first theory that specifically addressed the area of adult learning - which he termed andragogy. Knowles (1984, p. 12) defines andragogy as “the science and art of helping adults to learn”. Knowles’ work is specifically related to the concepts of negotiation in learning and learning contracts. Knowles argued that learning in adults is not suited to the methods of learning which evolved for use with children - where it is the teacher who takes all responsibility. Knowles (cited in Smith, 2002) offers five core principles to his theory.

(i) The learners’ self-concept.

Adults need to have control of decisions affecting self-direction and any attempt by a teacher to impose their will on a student will be resisted. Adults will therefore need to know the relevance of what is to be learnt.

(ii) The role of the learners’ experiences.

Adults come to learning with a diverse and significant level of experience. This experience in many ways defines the student as an individual and this must be utilized by the teacher.

(iii) Readiness to learn.

When adults are able to perceive that learning is directly related to their lives, they will become ready to learn.

(iv) Orientation to learning.

Adult learning is life-centred rather than in the case of children where it is subject-centred. Adults will therefore learn most effectively when they are presented with information in context to real-life situations and where the use of knowledge is seen to be relevant and applicable.

(v) Motivation.

Knowles argues that the most potent motivating factors are those which the learner imposes on him/herself, such as increasing self-esteem or job satisfaction. Knowles stresses the importance of negotiation with the learner in order to determine the objectives of the learning experience and identifies many advantages in this method. In particular he considered it develops skills such as problem solving, negotiation, self-discipline, priority setting, communication, creativity and autonomy, which help the student to learn.

Knowles appears to concur with Rogers in that learning in adults should consider themes such as facilitation and self-centred learning where the student becomes actively involved in determining the nature and extent of the learning experience. These are reasonable assertions and will lead to a form of learning with intrinsic motivation and thus more persuasive and meaningful to students. Knowles' work has not however been universally accepted. Davenport (1987) notes semantic confusion in the term andragogy itself in which the role of the teacher appears to be emphasised. Day and Baskett (1982) suggest that andragogy is not a theory of adult learning at all and assert that rather it is an inquiry-based learning and teaching paradigm. These are valid criticisms and lead to a number of other issues in relation to the use an andragogical approach in relation to this thesis. Firstly, some employers may feel that self-actualisation of the individual may not be consistent with wider societal objectives (such as education as being concerned with economic regeneration). Secondly, it is unclear when students become self directed and some areas of learning may be unfamiliar to learners and previous experiences may be absent (this would appear to be the case in teaching some elements of theory relating to engineering for example). Thirdly, limitation in terms of resources may affect the capability of teachers to deliver some elements of an inquiry based learning strategy.

Kolb (1975) provides further development of the humanist theory with the development of an experiential learning model which rather than a series of outcomes, characterises learning as a process, which is affected by all aspects of a learner's life. Kolb's model consists of four elements: concrete experience, observation and reflection, the formation of abstract concepts and testing in new situations.

Kolb by considering learning as a holistic adaptation to the world views knowledge as created through the transformation of experience. Experiential learning is therefore a form of learning to be undertaken by students who are given the change to acquire and apply knowledge, skills and feeling in an immediate and relevant setting. Consequently, considering the vocational nature of engineering many instances for the possible use of experiential learning do appear to be offered. Rogers (2002) in discussing experiential learning highlights a further advantage in harnessing The Accreditation of Experiential Learning (APEL) and here evidence is again provided for possible uses in the context of this thesis.

Summarizing the humanist perspective significant advantages in its possible use do appear to exist. In particular by taking a holistic view to learning humanism is related to all aspects of a learner's life and growth and within this thesis this has already been established as desirable. Furthermore, by stressing the process of learning to learn and the autonomy of the learner, the humanist perspective emphasises that skills are transferable to new situations (this would be of clear value to employees and employers alike in raising economic performance). Androgogy specifically addresses the teaching of adults (including 16-18 year olds) and emphasizes the role of the teacher as a facilitator involved with the learner in a partnership or agreement and thus a complementary concept for teaching and learning exists. The humanist perspective of learning can also be noted in many current-day educational practices such as the application of life-long learning, APEL, learning in context and reflective practice.   Some limitations have however been proposed such that self-initiated learning is not always possible or that some complex elements of theory may require greater tutor input. Further, the humanist perspective of learning may is not compatible the instrumentalism and competency-based approach currently used within vocational education.

5.3.5 Constructivism.

Bruner (cited in Hart, 2000) views the constructivist perspective of learning as concerned with the level of prior learning an individual brings to the experience of learning. Reeves (1995) considered that constructivism recognises that a new understanding comes not only from teaching and the delivery of new knowledge but also from the beliefs and skills an individual possesses based upon their previous experiences. Brooks and Brooks (cited in Epstein and Ryan, 2002) define constructivism similarly by recognising it as the combination of prior learning, new information and a readiness to learn.

Constructivists therefore argue that individuals when learning will decide on what ideas will be accepted by fitting them into their previously established views as gained through prior experience. Weir (cited in Hsiao, 2006) provides proof of the effectiveness of cognitive constructivism from evidence that students involved in solving real-life problems exhibited greater motivation and deeper understanding of the concepts being investigated. Schön (1983) extends this principle through the concept of reflective practice by advocating that individuals learn and build new understandings by connecting theories with past experiences and their own feelings. This concept has had a profound effect on the linkage of learning theory through to practice and various models of work-based learning have evolved which seek to ensure that students are allowed opportunities to reflect upon professional and relevant real-life problems. Examples of this practice include cooperative programmes, the cognitive apprenticeship model, placements, field-work experience and joint-industry-university placements. These applications may appear to be more readily applicable to HE practices but viewed form an anthological perspective clear advantage in their use for the 16-18 year-old age group also exits.

Vygotsky (1978) argued that social interaction precedes development and thus demonstrates a social context to learning where more experienced teachers and other learners aid in the learning process. Social interaction is therefore seen as fundamental role in the process of cognitive development and learning becomes a reciprocal process between the teacher and the student within what is termed the zone of proximal development. Forman and Cazden (cited in Hsiao, 2006) provide evidence of the effectiveness of social constructivism by describing how students are initially provided with a learning environment in which students are encouraged to assist each other in problem solving activities where the students individually come to their own conclusions on what has been learned. Jonassen (cited in Hart, 2000) proposes a number of practical procedures to utilise the constructivist approach based on collaborative problem-based, contextualised methods with an emphasis on metagconitive development.

The constructivist position therefore differs from the traditional approach to teaching. The traditional view emphasises the careful formation of behavioural objectives to assist the mastery of a particular skill or subject. By contrast, the constructivist view emphasises activities designed to assist the student develop his own conceptions. A social-constructivist perception based on social and contextualised learning offers significant advantages in relation to this thesis and is therefore highly desirable. Firstly, learning within an engineering context must be directly related to meaningful skill acquisition or directly associated to a social, technical or economic context within the area of interest to the students. It is important that within the developed curriculum proposal students are not provided with mechanistic, linear, mainly cognitive learning opportunities. This is justified in that it can not be assumed that students will automatically transfer knowledge and skills gained to other settings. It is more important that students are provided with relevant, contextualised experiences which are coherent in presentation and applications. Secondly, recognition must be made of the social context within the majority of engineering activity takes place. Social and interpersonal skills leading to the development of metacognitive skills are therefore compatible to the manner in which employees within engineering companies operate. No contradiction between employer and employee requirements is present here since employers will benefit from socially confident employees. Thirdly, sufficient flexibility is encompassed within a social-constructivist approach to overcome discrepancies between the preferred modality of most students and the teaching and assessment methods most used in the teaching of engineering.

5.4 Learning styles.

As discussed in chapter 5.2 the definition of learning and how to facilitate learning is complex and multi-faceted. Consequently, accepting a definition of learning styles is problematic. Nevertheless, it is accepted that if students are taught in a manner consistent with their learning style, then learning will be facilitated (Rogers, 2002) (Robotham, 1999). Lockitt (1997) considers a learning style as the behaviour exhibited by a learner in response to a particular learning situation, as they perceive it, the response from the learner being affected by factors such as the learner's previous learning experience, character and cognitive ability. James and Gardner (1995, p. 20) define learning styles as "the complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn". Keefe (cited in Griggs, 1991) defines learning styles "as the composite of characteristic cognitive, affective and physiological factors, that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment". These examples highlight different interpretations of learning styles based on psychological factors (such as personality traits, intellectual ability and brain function) and learning styles are viewed as preferential in terms of individual learners and the situations of learning presented. A number of key models are now considered.

Kolb (1984) argues that every individual develops one or more preferred learning styles through experience. Based on the experiential learning model Kolb (cited in Rogers, 2002) identified four learning approaches which appeal in varying degrees to different kinds of people. Although identifying four different learning modes Kolb proposes that individual learners engage more fully in some learning modes more than others. Kolb and Fry (1975) proposed that this leads to four different learning styles termed converger (preferences for thinking and doing), diverger (preferences for experiencing and reflecting), assimilator (preferences for reflecting and thinking) and accommodator (preferences for doing and experiencing), see table 5(iv).

Honey and Mumford (1992) also identify four alternative predominant learning styles which are also based on Kolb's experiential learning model. These styles being termed activist, reflector, theorist and pragmatist. Table 5(v) summarises the characteristics of each learning style.

Learning style	Learning characteristic	Description
Converger	Abstract conceptualization + active experimentation	Practical application Unemotional; Has narrow interests
Diverger	Concrete experience + reflective observation	Strong imaginative ability Good at idea generation Interested in people Broad cultural interests
Assimilator	Abstract Conceptualization + Reflective observation	Strong ability to create theoretical models Excels in inductive reasoning Concerned with abstract ideas
Accommodator	Concrete experience + active experimentation	Likes doing things More of a risk taker Performs well under pressure Solves problems intuitively

Table 5(iv) Kolb's learning styles.
Source: www.infed.org/biblio/b-explrn.htm (2007)

Learning style	Characteristic
Activist	Involve themselves fully and without bias in new experiences. They are open-minded, not sceptical, and this tends to make them enthusiastic about anything new. They tend to thrive on the challenge of new experiences but are bored with implementation and longer consolidation.
Reflector	Like to stand back to ponder experiences and observe them from different perspectives. They collect data, both first hand and from others and prefer to think about it thoroughly before coming to any conclusion. Their philosophy is to be as cautious as possible. When they act it is part of a wide picture which includes the past as well as the present and other people's observations as well as their own.
Theorist	Adapt and integrate observations into complex but logical, sound theories and they assimilate discrete facts into coherent theories. They tend to be perfectionists who won't rest easy until things are tidy and fit into a rational scheme. They tend to be detached, analytical and dedicated to rational objectivity rather than anything subjective or ambiguous.
Pragmatist	Keen on trying out ideas, theories and techniques to see if they work in practice. Positively search out new ideas and take the first opportunity to experiment with applications. They like to act quickly and confidently and try out new ideas that attract them. They are essentially practical, down to earth people who like making practical decisions and solving problems.

Table 5(v) Characteristics of each learning style (Honey and Mumford).
Source: Honey and Mumford (1992).

The models provided by Kolb and Honey and Mumford have important implications in the selection of instructional activities. In particular they identify that teaching and assessment methods must allow for effective processing of information as received by the student. However, these models may be regarded as somewhat simplistic. Tennant, Jarvis and Anderson respectively (cited in Smith, 2005) highlight this issue concerning an overly simplistic assumption that only four different learning styles exist and point out that empirical support for the learning models is low and that different cultural experiences and conditions have not been fully considered. Kelly (cited in Pickles, 2006) supports this opinion by stating that different kinds of learning will have different learning styles for each. Atherton (2005) however highlights that using a relatively small number of descriptive learning styles does allow for the direct application of Kolb's experimental learning model and in the context of this thesis is a workable proposition and in particular the use of the model offered by Honey and Mumford (see chapter 7.2).

Minton (1991) provides an alternative categorisation of learning styles based on brain function. Minton proposes that the left-brain is responsible for logical thought, language, mathematical processes, reasoning and analysis and left-brain dominance leads to a preference to analytical behaviour. Milton states that the right-brain deals with rhythm, colour, spatial concepts, imagination and synthesis and that right brain dominance is characterised by patterns and wholes rather than by analysis. Honey and Mumford (1992) correlate right-brain dominance with activist and pragmatist styles and left-brain dominance with reflector and theorist styles. An alternative but complementary approach to understanding learning styles is based on the concept that memory is just a by-product of the depth of processing of information (Craik and Lockhart, 1972). Marton and Säljö (cited in Duff, 2000) extend this concept by defining two approaches to learning termed a deep approach and a surface approach. A deep approach is characterised by an intention to understand the meaning of what is being learnt, questioning the arguments being made, relating it to previous and personal experience and justifying conclusions by the evidence presented. A surface approach is characterised by memorising and a focus on facts or disconnected information often resulting in low levels of understanding. Gibbs (1992) provides guidance to teachers by identifying some of the conditions that encourage surface learning as a heavy workload, high contact hours, excessive course material, lack of choice over the teaching methods adopted and a threatening and anxiety-provoking system. Deep learning on the other hand being encouraged by project work, learning by doing, problem-based learning, group assignments, student reflection, allowing for independent learning, rewarding understanding rather than reproduction and allowing the students to participate in the choice of teaching methods (as issue addressed in this thesis). Entwistle (1992) also recognises issues relating to heavy student workload by stating that students will move towards what are termed surface and strategic learning styles which focus on the products of learning and the achievement of good grades. Entwistle also proposes that effective teaching and assessment strategies are those which encourage a deep approach to learning and involve a high level of intrinsic motivation.

It has been shown that differences in the definitions surrounding learning styles exist and this makes conceptualization difficult. However, a number of attempts have been made to categorise the various learning styles. Curry (cited in Young and Peterson, 2007) for example categorises research into learning styles based on cognitive personality style, information processing style, social interaction style and instructional preferences. Rayner and Riding (2000) consider three categories which are termed cognitive-centred, learning-centred and personality-centred. Riding (1991) provides a further definition in proposing a two-dimensional distinction of learners and learning types and highlights instructional elements in curriculum design. Riding offers wholist/analytic (corresponding to the ordering and content of instruction) and verbaliser/imager (corresponding to the presentation of instructional materials). Reid (1987) provided a categorisation of these learning styles as visual, auditory, kinaesthetic, tactile, social group and social individual.

Philosophical distinction must therefore be made between learning styles models. In the context of this thesis the most appropriate category is considered to be those learning style models which allow for the construction of pedagogic strategies. This is justifiable since this thesis seeks to construct a method for assistance in providing at the arrival at sound practical judgments concerning the selection of course content and of teaching and assessment methods. It does not seek to investigate the psychological aspects of learning style theory. In particular, careful consideration must be given to the selection and use of teaching and assessment methods which promote learning and cause learning to happen, and are complementary to differing learning styles. In this regard the importance of understanding learning styles can be said to lie with the requirement that effective teaching methods must be devised to ensure that the learning experience is successful. Within this thesis this demonstrates it is necessary to identify the range of learning styles preferred by engineering students, identify which teaching, learning and assessment methods best suit these preferences and consider what can be done to satisfy students whose learning styles may not be addressed.

Felder and Silverman (1988) in considering the selection of learning and teaching styles for engineering students provide guidance on the selection of appropriate teaching and assessment methods. In this application of learning styles theory added validity is provided through the integration of well established models. Jung's theory of psychological types (cited in Felder and Silverman, 1988) is used to propose a sensing and intuitive dimension to learning. Similarly, Kolb's experiential learning model is used to propose an active and reflective dimension. Other dimensions proposed are visual and auditory and inductive and deductive. This is a valuable study in a number of ways. Firstly, it relates directly to engineering education. Secondly, it draws a distinction between learning styles and teaching styles and thus complementary teaching methods are proposed against each preferred learning method. Thirdly, it identifies apparent discrepancies between the preferred modality of most students and the preferred teaching methods used in the teaching of engineering. This would appear to be an important factor since the use of a deductive teaching structure can be recognised within many present-day FE curricula. Competency-based qualifications for example neatly lay out a progression from fundamental principles to the subsequent application of theory. This is a familiar approach to the teaching of engineering but in identifying an alternative inductive approach Felder and Silverman supply a convincing alternative where application and observation precedes theory. This is surely a more realistic situation when engineering is viewed in its vocational context. Secondly, accepting that engineering education tends to be fundamentally sequential and deductive then the preferred learning styles of many students can not be fully satisfied and possibly higher level skills such as creativity may be adversely affected. If traditional teaching of engineering does tend to favour abstract perceiving and reflective processing then other kinds of learning aren't being sufficiently reflected in the curriculum, instruction and assessment.

From the preceding discussion a number of other issues also emerge which merit consideration. Firstly, there is a danger that prescriptive use of a learning style model may result in unnecessary and inappropriate categorization of students. Kolb (1976) recognised this by not seeing the learning styles of a learner in a singular compartmentalised fashion and argues that a style inventory will place the learner on a continuous line within the experiential learning model. This appears to a reasonable assumption and in accepting this it must be acknowledged that this predisposition can often distort the learning process and highlights the fact that teachers need to devise techniques that will assist learners develop a more holistic approach and ensure that all stages of the learning cycle are covered.

Secondly, it must be debatable to assert that adults have a single set of preferred learning styles. Surely a more accurate position would be to acknowledge that preferred learning styles will not be used in all situations. This would be significant from the perspective of this thesis (where much of the learning for 16-18 year olds within engineering will be within the psychomotor domain).

Thirdly, the exact correlation between learning style models and established behavioural and personality theory remains unproven. The scientific basis for some of the learning theories can therefore be questioned. Coffield, et al., (2004) support this view by concluding that inadequate validity exists for the use of learning preferences and the value of matching teaching and learning styles is unclear.

A solution to these issues would appear to lie with providing a broad range of teaching and assessment experiences so that educators connect with all learning styles using various combinations of instruction to facilitate the development of each student. This conclusion has support (Entwistle, 1991) (Honey and Mumford ,1992). At the very least it can be said that learning style analysis will provide the student with an insight into their own strengths and weaknesses and assist students in the development of metacognitive reflection about their own learning processes.

5.5 Assessment strategies.

In the preceding discussion on learning theory and learning styles the critical importance of selecting and using appropriate assessment strategies and methods has been established. Despite continued emphasis on the importance of assessment it is debatable if a clear definition exists. Airasion (cited in Phye, 1997) views assessment as concerned with information gathered by the teacher to monitor student progress. This definition appears to blur the distinction between gathering information about student achievement and a broader ethos about empowering students to learn. Baker and Stites (1991) view assessment as a demonstration of cognitive and non-cognitive characteristics in a range of contexts (including their workforce readiness). Despite differences in interpretation both definitions illustrate the importance that any form of assessment should, from a pedagogical point of view, have a clear and justifiable link between objectives, assessment and outcomes and include appropriate teaching and assessment methods. However, it is clear that differences in perspective for various audiences demonstrate theoretical distinctions. Nevertheless, in the context of this thesis it is reasonable to assume that employers are more concerned with the acquisition and exploitation of skills and here the definition offered by Baker and Stites has more resonance. Accepting the importance of the employer perspective a social-constructivist conceptual framework borrowing from cognitive and constructivist theories has already been identified as desirable in terms of student development. Thus, compatible and complementary assessment methods must be identified to support this viewpoint.

Race, et al., (2005) provide valuable guidance in the design of assessment and in particular stress that assessment must be valid, reliable, fair and authentic. Authenticity has already been highlighted within this thesis and the importance of assessment in encouraging the attainment of deep-learning, the desirability for skills to be transferable to new situations, reflection and relevance to real-life problems. This requirement also highlights linkage between the selection of assessment tasks in relation to the domain and level of learning being encountered and the preferred learning styles of the student.

The preceding points serve to illustrate that assessment should not merely be about the attainment of qualifications. It must also be the process by which it is ensured that learning and understanding has taken place. Robinson (1987) supports this viewpoint by stating that the purpose of assessment must not become associated solely with achievements or rewards and instead it should be a means of checking performance and understanding. Robinson extends this point by considering that an over-emphasis on assessment can also have an adverse effect on how institutions plan and deliver curricula (which is often in an attempt to maximise results). Robinson states this can also be found when individual tutors design assessments to maximise the performance of their own students in an attempt to improve their own perceived performance. Gibbs (1995) appears to concur with this opinion by stating that assessment is now more controversial, particularly when the outcome of the assessment is linked to the funding of educational institutions. Consequently, it must be acknowledged that not all assessment should be directly linked to the award of a qualification. Conversely, assessment methods should also be used to monitor performance, record progress, identify areas for improvement and provide the learner with feedback on the effectiveness of the learning process itself. Assessment methods chosen must therefore be carefully planned and implemented and be complementary to the teaching and learning model.

Assessment for student learning and of student performance has been shown to be a crucial quality issue and here principles and procedures of taxonomies for good assessment practice are of interest. Nichol (2007) in providing a series of good principles for good assessment links the importance of this issue to student motivation and in particular stresses students should be consulted in the process of assessment method selection. This is an important issue in relation to this thesis as students will be consulted in relation to preferred learning and assessment methods. Nevertheless, despite acknowledging the desire to consult students regarding preferred assessment methods it must surely be required to ensure that selected methods are defensible and coherent in terms of the overall teaching and learning philosophy. Therefore, formative, summative and informal assessment methods are viewed as the most appropriate.

As confirmed previously there has been a trend in vocational education towards the greater use of competency-based assessment through the use of criteria referencing. This is consistent with political and social trends towards the use of assessment methods which correlate to the need to raise skill levels and achievement in employment. Specifically in relation to engineering the inclusion of a relevant National Vocational Qualification and a technical certificate within the Modern Apprenticeship Framework are clear examples of where these principles are used to provide formal recognition of occupational competence in the workplace. Competence is defined against detailed criteria-based assessment statements within a specific occupational area and is not related to the performance of other students. In order to satisfy individual criteria the assessment is typically undertaken via the construction of a portfolio of evidence which can take a variety of forms (including documentation, direct observation, witness statements, reports or even practical artefacts produced by the student). Freeman and Lewis (1998) highlighted issues relating to assessment within the development of the competency-based vocational educational model such as currency, sufficiency and authenticity. They argued that any assessment must ensure that evidence provided is current and relevant to existing practice, sufficient to demonstrate learning in the area being considered, authentic and attributable to the learner. Clearly these issues are of particular concern within the assessment of engineering learning as technical changes can often occur at a fast rate and where technical information, data or indeed physical artefacts are often used in assessment situations.

Ecclesstone (1996) is a typical proponent of this form of assessment. Ecclesstone argues that this form of assessment has a number of advantages including that it is more relevant to the demands of the workplace and that a more accessible and relevant modular style structure allows for greater flexible in delivery. This may in turn better reflect the requirements of the apprentice and encourage apprentices to take more responsibility for their own assessment. This approach has however resulted in the considerable use of continuous assessment (in some cases replacing fully the use of terminal examinations). This compares to general education where greater emphasis is placed on knowledge recall and where the teacher would take the lead role in assessment (typically completed in the form of and normative and summative examinations). Although not wholly consistent with the social-constructivist perspective offered within this thesis the inclusion of criterion-referenced assessment is well embedded within vocational education and opportunities clearly exist for its integration with alternative methods of assessment. Race (2007) supports this view by stating that in practice different forms of assessment may be used within individual courses and this is considered appropriate and beneficial.

5.6 Review of learning theory and curriculum modelling.

The dominant learning theories currently used in the teaching of engineering are largely behaviourist and cognitive. Behaviourism is complementary to the setting of learning outcomes associated with facilitating the gathering of knowledge. Evidence for the use of a behaviouristic model has been presented in the use of NVQs and the widespread use of criteria-referenced/competency-based standards within engineering education. The consequences of this approach is a sequential, hierarchical and explicit teaching concept in which motivation is predominantly external and in which testing is frequently used to demonstrate learning. The cognitive approach is more suited to objectives concerned with problem solving (an area of particular importance within the psychomotor and cognitive domains of learning). Cognitive theory recognises the role of the mind and that learning is an active process of mental construction. What may not be so well appreciated in the delivery of engineering education is the development of affective abilities. In this sense the humanist perspective (with its emphasis on learning being applied to new situations) and the constructivist perspective (with its emphasis on high level processing, reflection and social relevance/interaction) would appear be of particular benefit and has been proposed as an advantageous model.

Elements of a cognitive theory to learning such as the consideration of prior learning and the use of a relevant context within learning activities are also considered advantageous and the Gestalt approach would appear to be appropriate for learners within the age group included in this work. Greater efforts to develop right brain thought would be beneficial and engineering courses would gain from further underpinning of critical cross functional elements to develop scientific, technical, creative and social skills. Ideally, this should be provided in the real-life context through structured work experience.

As highlighted previously it is considered that the proposal should utilise characteristics of the humanist school such as ensuring a holistic view to learning and the growth of the individual. The use of facilitation is therefore recognised as important and will clearly impact on the selection of teaching methods although the full extent to which facilitation should be used for the age group of the learners studied is debatable. Furthermore, elements of reflective practice should be included within the proposed curriculum to ensure that students are provided with an opportunity to relate relevant theory to real life applications and problems. This would also be advantageous in encouraging the independent development of metacognitive, transferable and generic skills. This approach should also be reflected in the manner in which transferable (key) skills are developed and it is proposed that first year students be taught these skills, but in the second year, transferable skills are developed though embedding them within each taught module.

Delivery of engineering courses should not be piecemeal with some vague promise from the tutor of a revelation in understanding at some point in the future. Learning must be seen as a process towards understanding of the whole and not just discrete unit-by-unit mastery. Students should be encouraged to recognise problems for themselves, how to identify solutions and how to transfer knowledge and skills gained from one context to another. This could involve reducing the content of courses and increasing the opportunities for practice, ideally within an industrial setting through prolonged work experience. The content of the final course proposal should be structured to allow coherent progression through the award. Clear linkage must be established between different areas of study, content and learning should be progressive through from simple concepts and changes in behaviour to more advanced stages. In practical terms, after establishing the learning objectives the curriculum proposal needs to clearly establish the domain(s) of learning within which it will operate. Taking account of prior learning and experience coverage of the entire learning cycle should be ensured and progression through relevant taxonomy levels identified.

In selecting assessment strategies to be included within the curriculum proposal it is necessary to consider the most appropriate methods which are compatible and support a social-constructivist model. Therefore, it is proposed that assessment methods be chosen which are consistent with the stated purpose of the learning methods. That is to say they should be selected to encourage transferable skills and to allow students to use the knowledge and skills gained to maximum effect in real-life situations.

Selected assessment methods should also recognise that assessment be relevant and challenging and provide students with self-sufficiency in learning and that minimum standards of achievement and knowledge be rigidly applied. Assessment practice therefore needs to account for the progression of the student in developing a complex understanding and application of the knowledge and skills gained. Learning and application of learning must not be downgraded in favour of an over-emphasis on assessment. Open-ended performance tasks should be preferred to encourage critical reasoning and problem solving applied in real-world contexts. Classroom practice therefore needs to reflect this ethos and formative, informal and summative assessment including the use of demonstrations, interview and projects appear appropriate. It was therefore decided to include formative, informal and summative assessment within the curriculum matrix (see chapter 8.3).

In summary, a range of curriculum characteristics considered to be desirable have been identified and justified for inclusion within the final curriculum proposal. The fully developed curriculum proposal should be based on the fundamental principles of: (a) technical knowledge, (b) transferable professional, social and generic skills,

(c) personal development and (d) practical application. This proposal is essentially more liberal than the technocratic system which is used currently and the salient features of the proposal are shown in table 5(vi).

Characteristic	Details
Identifying and analysing needs	
Student perspective	Development of skills, personal development and contextualised to real life situations.
Employer perspective	Development of skills as per QFD results and contribution to company success.
Course rationale, aims and objectives	
Student perspective	Employability and personal development
Employer perspective	Employability skills
Function of the course	Holistic growth of student
Learning perspective	Learner-centeredness, APL/ APEL considered relevance to life and work.
Detailing course syllabi	
Content	Development against competency profiles
Context of learning	Practical , real life applications, reflective
Duration	2 years (incremental advancement in each taxonomy).
Teaching and learning strategies	
Consideration of learning styles	Activist / pragmatist styles preferred.
Teachers role	Progressive use of facilitation, organising
Teaching methods	Correlated to taxonomy levels 1-3
Learning methods	Participation and discovery styles preferred.
Assessment strategies	
Assessment strategy	Knowledge based initially leading to self-sufficiency and metacognition
Frequency	Formative informal and summative.
Resource planning and acquisition	Appropriate to remainder of proposal.
Management of the course	
Location of delivery	College and work based.
Management / organisation	Facilitation.
Curriculum organisation	Correlation to needs to industry and student. Modular and differentiated.
Monitoring and evaluation	
Guidance and counselling	Equality of opportunity and experience.

Table 5(vi) Salient features of the curriculum proposal.

5.7 Provision of engineering education for 16-18 year olds within Coleg Sir Gâr.

Dearing (1996) established a comprehensive relationship between vocational and academic qualifications and was responsible for the establishment of the National Qualifications Framework (NQF) comprising five levels of occupational and educational attainment, see table 5(vii). In relation to this thesis levels 1, 2 and 3 within the framework covered the education of 16-18 year olds. In January 2006 the NQF was replaced (within England, Wales and Northern Ireland) by The Framework for Higher Education Qualifications (FHEQ) and learners are currently identified across eight levels rather than five (this structure does not apply to NVQs). Levels 1, 2 and 3 of the NQF were unaffected by the alterations but level 4 of the NQF framework has now been divided into three levels (termed levels 4, 5 and 6). Level 5 of the NQF framework, has now been divided into two levels (termed levels 7 and 8): The Quality Assurance Agency for Higher Education (QAA) (2008).

Qualification level	General education	Vocational education	Occupation
5 – Higher level	Degree level, post graduate level	Degree level	NVQ level 5
4 – Higher level		HNC / HND / Foundation degree	NVQ level 4
3 – Advanced level	A level	NC/ ND/ Vocational A level, AVCE	NVQ level 3
2 – Intermediate Level	GCSE – grade A-C	First diploma / certificate	NVQ level 2
1 – Foundation level	GCSE – grade D-G	Introductory awards	NVQ level 1

Table 5(vii) National Qualifications Framework
Source: Dearing Review (1996)

Upon completion of compulsory schooling, individuals entering a career in engineering essentially decide on either an academic or a vocational route for their career development. Despite diversity in the provision of engineering education for

16-18 year olds the following courses can be taken as indicative of the general and vocational routes.

Academic *Route*

GCE AS/A2 levels (full-time mode of study).

International Baccalaureate (full-time mode of study).

Vocational Route

NVQs (flexible delivery).

First Diploma (FD) award (full-time mode of study).

National Certificate (NC) / National Diploma (ND) awards (part-time / full-time).

Within Coleg Sir Gâr students taking the academic route will complete appropriate General Certificate of Education Advanced awards over a two year period. Students taking the vocational route (but not in full-time employment) will complete a full-time course of study, such as the National Diploma - which is equivalent to three GCE Advanced (A) levels: Learning and Skills Council (LSC) (2008). Students taking the vocational route (and in full-time employment) do so as part of a Modern Apprenticeship programme which includes a Technical Certificate, such as a National Certificate - which is equivalent to two GCE A levels: LSC (2008).

5.7.1 The academic route into engineering within Coleg Sir Gâr.

The GCE Advanced Subsidiary (AS) award is intended to build upon the knowledge and skills gained through the study of complementary subjects at the General Certificate of Secondary Education level. It also enables students to gain a foundation for progression to A2 GCE level. Full advanced level awards are available on the subsequent completion of the A2 units which are intended to build on the work at AS level by introducing a greater degree of complexity and understanding: Edexcel (2007). GCE AS and A levels are available in a wide range of subject areas. In relation to engineering the following subjects can be accepted to be the most significant: engineering, mathematics (includes pure mathematics, mathematics and further mathematics) and physics.

The GCE engineering award provides a broad introduction to engineering in a work-related context and the award is intended to form the basis of further training, progression to Higher Education or into employment: Edexcel (2007). In terms of its structure the GCE in engineering is a single award and in line with other GCE single awards comprises six equally weighted units, containing an AS subset of three units. As usual the AS is the first half of a GCE A level and contributes 50 per cent of the total Advanced GCE marks. The AS award is completed within one year with the A2 award (and therefore the full award) taking a further year of study: Edexcel (2007). The unit titles and assessment regime for the engineering GCE award are provided in appendix 5.

The GCE Mathematics Award comprises the individual awards of mathematics, further mathematics or pure mathematics. There are eighteen units from which to select, each designated as either AS or A2 units and again the full Advanced GCE has six units with the Advanced Subsidiary award consisting of three units. Different combinations of units lead to different awards although the study of a particular unit is dependent on the study of all preceding units within that area of mathematics:

Edexcel (2007). The unit titles and assessment regime for the GCE Mathematics are provided in appendix 5. The GCE Physics award again follows the familiar pattern of the AS and A2 stages. The unit tiles and assessment regime for the GCE Physics award are provided in appendix 5.

5.7.2 The vocational route into engineering within Coleg Sir Gâr.

As highlighted in chapter 4.2 technical and vocational education is of particular interest in relation to this thesis. In the case of 16-18 year olds pursuing the vocational route into engineering the preferred method is largely depend on the chosen mode of study. Full-time students undertake a First or National Diploma. Students in part-time study are modern apprentices (see chapter 5.6.3).

First Diplomas (located at FHEQ level 2) are vocational qualifications and are designed to provide opportunities for students wishing to either obtain employment or progress to further study at FHEQ level 3 (QAA)(2008). First Diplomas are available in a number of vocational engineering areas including electronics, manufacturing engineering and vehicle servicing engineering. The award comprises six modules, three of which are mandatory and three of which are specialist units. The award is primarily designed to prepare students for the world of work and as such provides for opportunities to gain NVQs as well as Key Skills: Edexcel (2007). The delivery mode is full-time over a full academic year with the majority of the delivery being conventional classroom contact. All assessment is criteria-referenced based on the achievement of specified outcomes. The criteria is contextualised within the modules and individually identified as pass, merit or distinction. To achieve a pass grade for the unit the learners must meet the assessment criteria set out in the specifications. Assessment is primarily completed internally with additional internal verification and national sampling undertaken to ensure quality assurance.

A National Diploma is an eighteen unit award comprising six core and twelve specialist units :Edexcel (2007). National Diplomas have been designed to be related to occupational standards and therefore provide for underpinning knowledge and understanding in key engineering areas such as design, production and technical support : Edexcel (2007). A list the core and specialist modules available for each of the mechanical, manufacturing, electrical and electronic streams are provided in appendix 5. Students are also provided with opportunities for acquiring practical and generic skills. Assessment of the National Diploma is criterion-referenced and therefore based on the achievement of specific outcomes with the grading criteria being contextualised within the unit. Students are individually identified as obtaining either a pass, merit or a distinction. To achieve a pass grade for the unit the learners must meet the assessment criteria set out in the specifications. Assessment is conducted internally with internal verification and national sampling undertaken to ensure quality assurance.

5.7.3 Education for engineering apprentices within Coleg Sir Gâr.

Modern Apprenticeships are a combination of work-based training and formal education and are intended to raise the skill levels and participation rates of young people in business**:** LSC (2008). Modern Apprenticeships are available at two levels, these being the Foundation Modern Apprenticeship (FMA) at level 2 of the FHEQ and the Modern Apprenticeship at level 3 of the FHEQ: LSC (2008). Engineering

Modern Apprenticeships are predominately at level 3 of the framework and the following elements must be completed.

- A National Vocational Qualification. Modern Apprentices are currently required to complete a minimum of eight units from an appropriate standard including all the mandatory units plus others deemed suitable for their career needs.

- Modern Apprentices are required to complete level two Key Skills in Communications, Application of Number, Information Technology, Working with Others, Improving Own Learning and Problem Solving.

- A Technical Certificate approved within the framework such as a National Certificate, National Diploma, Edexcel National Award in Engineering or the City and Guilds Certificate in Engineering.

- Other mandatory or optional elements as required within a specific occupational area.

NVQs

National Vocational Qualifications are available at five levels: QCA (2008). In terms of 16-18 year olds completing NVQ awards, levels 1 to 3 are the most important. At level 1 a candidate must demonstrate competence in a range of activities that are largely routine and predictable. A Level 1 qualification is therefore intended for employees looking to attain and demonstrate basic skills. At level 2 candidates must demonstrate competence in a broader range work activities which are less routine and predictable and where some autonomy and responsibility is required. Level 2 qualifications are therefore intended for semi-skilled employees. At Level 3 candidates must demonstrate competence on a broad range of varied work activities most of which are complex and non-routine. There will also be considerable autonomy and responsibilities required at level 3, with the possibility of managing others. Level 3 awards are therefore intended for employees working in technician, craft, skilled and supervisory positions.

As described in chapter 2.2.1 NVQs are based on industry standards which must be met to demonstrate competency in a particular task. Each award is made up of a number of units which need to be completed in order to achieve the full award. Within Coleg Sir Gâr the preferred award undertaken by 16/18 year olds within engineering (either within the apprentice framework or within the workplace) is the NVQ in Performing Engineering Operations (PEO), see appendix 5 for the full list of units. To achieve the NVQ candidates at level 1 must complete two mandatory units and a further two optional units selected from a choice of sixteen options - additional units can be completed if required. At level 2 the candidates must complete three mandatory units and a further one optional unit taken from group A (general support units) and a further two units from group B (optional units). NVQs are delivered as roll on-roll off programmes and therefore provided the necessary planning has been completed candidates can start their NVQ at any time. No time limit is set for the completion of the NVQ. The timing of assessment will depend on the needs of the candidate although it is considered good practice to enforce a target date for completion. Typical assessment methods used include observation, product evaluation, questioning and the generation of evidence through assignment work/logbooks. Regardless of the assessment method employed the assessor must ensure that they are valid, reliable and practicable

Key Skills

The introduction of Key Skill attainment was justified as a response to the demands of employers having complained about the lack of basic numeracy and literacy demonstrated by students leaving full-time secondary education (Charter 2002). The FHEQ identifies six Key Skills: Communication, Application of Number, Information Technology, Working with Others, Improving Own Learning and Problem Solving all of which increase in complexity in line with the levels within the FHEQ framework (SEMTA 2008)**.** Engineering students at Coleg Sir Gâr are expected to complete Key Skills in the core areas of Communication, Application of Number and Information Technology. The level of Key Skill attainment is commensurate with the level of study being undertaken, e.g. level 1 Key Skills for First Diploma, level 2 for first year NC/ND/A level students and level 3 for second year NC/ND/A level students. An integral part of the Modern Apprenticeship programme for engineering occupations is the acquisition of all Key Skills at level 2.

Key Skills are assessed though criterion-referenced standards and the candidate is expected to construct a portfolio of evidence which is presented to an assessor as a means of demonstrating the requirements of the standard has been met. This normally takes the form of a technical report or assignment.

Technical Certificate

Within Coleg Sir Gâr the National Certificate is the preferred Technical Certificate and offers a programme for students already clear about their intended area of employment (such as Modern Apprentices). Alternatively, individuals seeking employment in specific areas or those students already in employment wishing to attain a suitable formal qualification also complete the NC. Delivery of the NC is flexible, although usually it is delivered on a part-time basis over a two year period. The qualification provides for sign posted opportunities for the development and attainment of Key Skills at both levels two and three. In the case of Modern Apprentices the National Certificate is also a vehicle for the attainment of key skills. Again restrictions are placed on module selection and in the case of a National Certificate a minimum of four specialist modules must be chosen from "Group A" (see appendix 5).

5.8 Review of provision of engineering education for 16-18 year olds at Coleg Sir Gâr.

Comparing the features of the curriculum proposal against the vocational and general awards several observations can be made.

In terms of the vocational route the various awards have broadly similar philosophical perspectives. These competency-based awards do however have an over-emphasis on behaviourist theory which is incompatible with the wider (more general) aims identified in the curriculum proposal. The vocational awards identify skill as the ability to perform tasks but greater attention needs to be paid to how knowledge and theory are acquired, assimilated and applied to a different context. It is insufficient to assume that creative, expressive and logical abilities can be delivered by embedding them with the technical modules or by delivering bespoke Key Skills.

The general route does have the advantage of pursuing a more liberal interpretation of the purpose of education and thus the development of the individual across a wider definition of learning is achieved. However, it is debatable whether the specific competencies required by employers could be fully satisfied in this manner. In this respect it is considered that an appropriate balance has been developed within the final curriculum proposal.

Existing vocational provision is broadly philosophically consistent with the curriculum features considered desirable (particularly with regard to satisfying employer requirements). However a competency-based approach does not fully satisfy the wider humanist elements of the curriculum. In this regard general education (if adopted in a constructivist, liberal manner) is arguably better able to develop wider generic skills in students. Greater effectiveness of the vocational model can be achieved by assimilating these features, especially with regard to considering how theory and practice can be combined in a creative manner and applied to a new situation or context.

The importance of delivering engineering in a relevant context has been highlighted previously. On comparing of the vocational and general educational routes it is clear that the vocation route is best to provide for practical real-life learning experiences. However, it is debatable whether the vocational awards considered are sufficiently integrated to allow for incremental advancement of skills and knowledge. In this respect piece-meal delivery of individual modules must not prevent the development of the students to a point of self-sufficiency.

In comparing the content of each alternative route it is considered similar differences to those highlighted above can be identified. Firstly, in terms of the vocational awards there is a clear modular approach. A clear emphasis on vocational content reflects the requirements of the employers. This is less evident within the narrower list of subject areas encountered on the awards on the general route of education. Therefore, with the judicious selection of modules (as per the final curriculum proposal) individual educational establishments can better satisfy employer requirements with the delivery of vocational awards. However, the delivery of these vocational modules must be augmented with those attributes of general education previously identified to ensure the holistic development of the student.

In summary, on comparing vocational to general education differing philosophical foundations have been confirmed. Vocational awards are a form of instrumental education where the overriding aim is to raise economic performance. General education is more liberal than vocational education and an egalitarian emphasis is placed on democratic participation. It is argued in this thesis that economic performance is of primary importance to engineering education but this can not be achieved without proper consideration of the learners. Therefore, although specific occupational, vocational and generic competencies are required, delivery should account for coverage of the entire learning cycle, across all domains of learning and incorporate both humanist and constructivist elements.

5.9 Chapter summary.

At the start of this chapter two key issues were identified. Firstly, in recognition of the need to develop the final curriculum proposal in a complementary manner to the requirements of the engineering students this chapter was used to explore elements of learning theory and related curriculum planning issues. Appropriate curriculum characteristics for incorporation into the final curriculum proposal have been identified and justified. Complementary learning, teaching and assessment methods and course management features are identified - all of which are philosophically consistent with the purpose and context of learning within this thesis. These characteristics will be assimilated into the final curriculum proposal.

Secondly, to allow for an evaluation of the effectiveness of existing engineering educational provision this chapter has been used to investigate a range of awards (within the 16-18 year age group in Wales) and the existing Modern Apprenticeship framework within Wales. These awards were subsequently compared against the preferred characteristics of the final curriculum proposal and observations made in terms of existing provision.

CHAPTER 6

IMPLEMENTATION - DATA GATHERING (EMPLOYER REQUIREMENTS)

The output of chapter 4 was a listing of the salient economic, technological and occupational drivers impacting on engineering organisations within the UK. Specifically in relation to the education of 16-18 year olds and a range of engineering companies within the South Wales region primary data to confirm and supplement these findings was collated and this chapter is used to present those results.

The output of this chapter is a prioritized listing of specific competencies that these employers will require in the future. This data forms the input (the customer requirements) to the QFD product matrix (see chapter 8).

6.1 Introduction.

The approach taken used was to cross-reference the drivers of change against specific competencies, see table 6(i). Competencies were subsequently classified as technical, professional and business skills, information handling skills or generic, see table 6(ii).

Driver of change – Economic	
Internal factor	**Competency**
Sensitivity to exchange rate changes	Business awareness. Commercial and profit focus. Business development.
Sensitivity to interest rate changes	Business awareness. Commercial and profit focus. Business development.
Sensitivity to inflation rate changes	Business awareness. Commercial and profit focus. Business development.
Sensitivity to taxation rate changes	Business awareness. Commercial and profit focus. Business development.
Labour costs	Business awareness. Commercial and profit focus.
Materials sourcing policies	Business awareness. Commercial and profit focus. Business development.
Overhead costs	Business awareness. Commercial and profit focus.
Supplier selection	Business awareness. Commercial and profit focus. Business development. Logistics and supply chain management. Materials flow technology. Customer focus. Integrity. Building relationships. Drive and confidence.
Return on investment policy	Business awareness. Commercial and profit focus. Business development.
Acquisition policy	Business awareness. Commercial and profit focus. Business development. Customer focus. Integrity. Building relationships. Drive and confidence.
Pricing policy	Business awareness. Customer focus. Business development.

Level of marketing / marketing policy	Business awareness. Commercial and profit focus. Business development. Customer focus. Drive and confidence.
Level of capital investment	Business awareness. Commercial and profit focus. Business development. Customer focus.
Location of production	Business awareness. Commercial and profit focus. Business development.
Level of financial planning and control	Business awareness. Commercial and profit focus. Business development. Customer focus. Leadership.
Returns to investors	Business awareness. Commercial and profit focus. Business development.
Strategic business planning	Business awareness. Commercial and profit focus. Business development.
Level of borrowing	Business awareness. Commercial and profit focus. Business development.
Customer support polices	Business development. Customer focus. Persuasiveness. Presentational skills. Communication skills. Time management. Building relationships. Integrity.

Driver of change – Technological

Internal factor	**Competency**
Level of R and D investment	Business awareness. Commercial and profit focus. Business development. Product development. Advanced technology /CAD/CAM. Manufacturing technology.
Level of supply chain integration	Logistics and supply chain management. Materials flow technology. Business awareness. Commercial and profit focus. Business development. Persuasiveness. Building relationships.
Level of patent generation (design activity)	Advanced technology / CAD/CAM. Manufacturing technology. Materials flow technology. Product development. Creativity. Team working. Leadership.

	Project management.
Productivity levels	Advanced technology / CAD/CAM. Manufacturing technology. Materials flow technology. Product development. Business development.
Exploitation of new materials/processes	Advanced technology / CAD/CAM. Manufacturing technology. Materials technology. Cleaner production. Sustainable manufacture. End of life management.
Development of new products	Advanced technology / CAD/CAM. Manufacturing technology. Materials technology. Sustainable manufacture. End of life management. Creativity. Team working. Leadership. Project management. Time management. Innovative thinking.
Exploitation of new energy sources	Sustainable manufacture. End of life management.
Design policy	Business awareness. Commercial and profit focus. Business development.
Outsourcing policy	Business awareness. Commercial and profit focus. Business development.
E-commerce / IT exploitation	Ability to exploit IT. Innovative thinking.
Quality of supply / design / production	Quality management.
Production strategy	Practical craft skills. Advanced technology / CAD/CAM. Manufacturing technology. Materials flow technology.
Maintenance strategy	Practical craft skills. TPM
Lead times/ delivery times	Business awareness. Commercial and profit focus. Business development.
Commitment of continuous improvement and lean manufacturing	Business awareness. Commercial and profit focus. Business development. Quality management
Production alliances	Business awareness. Commercial and profit focus. Business development. Quality management
Level of diversification	Business awareness. Commercial and profit focus. Business development. Quality management

Knowledge capture mechanisms	Problem solving ability. Ability to exploit IT. Innovative thinking.
Driver of change – Occupational	
Internal factor	**Competency**
Recruitment policy	To complement company’s aims and objectives and in consideration of relevant external constraints.
Remuneration policy	As above.
Education and training policy	As above.
Occupational balance	As above.
Organisational structure	As above.
Management polices / corporate style	As above.
Work patterns	As above.
Partnerships with educational institutions	As above.
Trade union policy	As above.
Interdisciplinary / mutli-skilling	As above.
Recruitment of apprentices	As above.
Recruitment and retention of core workers	As above.
Multi-cultural polices	As above.
Skills required – professional / business	From above: Business awareness Commercial and profit focus. Customer focus. Business development. Persuasiveness. Drive and confidence. Presentational skills.
Skills required – technical	From above: Product development. Advanced CAD/CAM. Practical craft skills. Manufacturing technology. Material flow technology. Cleaner production. Sustainable manufacture. Project management. End of life management. Logistics and supply management. Quality management.

Skills required – information handling	From above: Numeracy. Ability to exploit IT Higher mathematical ability Problem solving. Innovative thinking.
Skills required – generic	From above: Leadership. Team working. Creativity. Communication skills. Project management. Multicultural skills Time management. Integrity. Building relationships.

Table 6(i) List of drivers of change against competency areas.

Technical Skills	**Professional and Business Skills**	**Information Handling Skills**	**Generic Skills**
Product development	Business awareness	Numeracy	Leadership
Advanced CAD/CAM	Commercial and profit focus	Ability to exploit IT	Team working
Practical craft skills	Customer focus	Higher Mathematical ability	Creativity
Manufacturing technology	Business development	Problem solving	Communication skills (verbal and written)
Material flow	Persuasiveness	Innovative thinking	Project Management
Cleaner production	Drive and confidence		Multicultural skills
Sustainable manufacture	Presentational skills		Time management
Project management			Integrity
End of life management			Building relationships
Logistics and supply management			
Quality Management			

Table 6(ii) List of specific competencies identified.

6.2 Data collection method.

After the identification of the relevant competencies it was possible to design an employer questionnaire and apply it to a range of local employers to ascertain their actual requirements for the future (see chapter 3.2.1).

The employers were interviewed individually with the questionnaire being completed during the interview by the interviewee. This method although more time consuming than a traditional mail-shot did allow for individual discussion and therefore an opportunity to explore and interpret the more complex issues which may have been difficult to identify merely through the completion of the questionnaire by the interviewee alone.

6.3 Participants in the employer survey.

In order to accurately reflect the extent of local and regional engineering activity it was decided to limit the investigation to only three quadrants of the Puttick grid (omitting the top right hand quadrant, which relates to companies operating in markets of high uncertainty but producing products of low complexity). Each company participating in the survey was selected by considering the nature and extent of their business and in this manner it is possible to ensure an adequate coverage of the remainder of the Puttick grid. Each organisation was also requested to provide a senior and suitably experienced member of staff to participate in the study.   A full list of the companies and their representatives involved in the survey follows and figure 6.1 indicates the perceived position of each organisation in the Puttick grid.

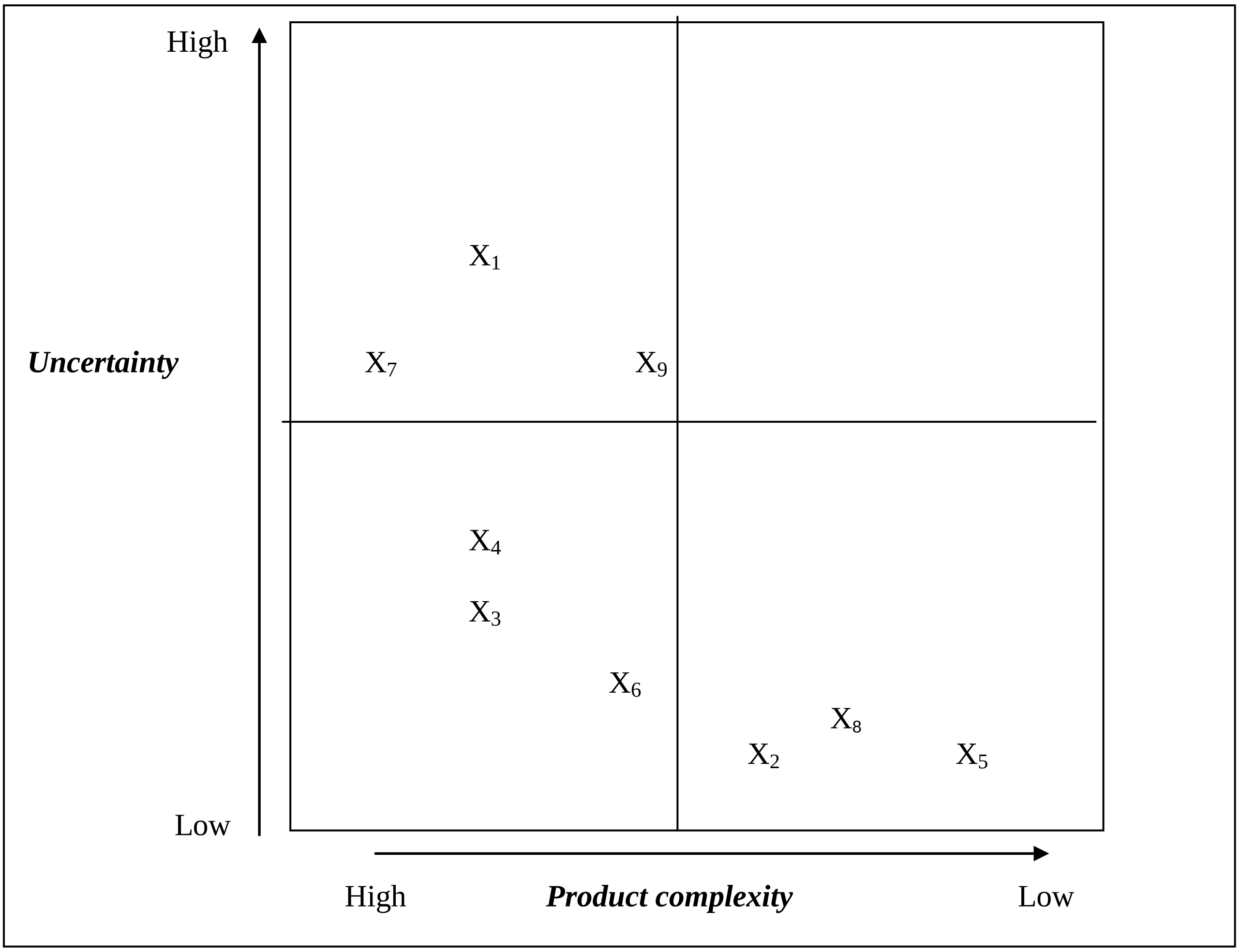

Figure 6.1 Puttick grid positions.

X_1 = Magstim Company Limited, represented by Ms J Lewis, Quality Manager.

X_2 = Alcoa Europe, represented by Mr Steven Evans, Roll Shop Manager.

X_3 = Calsonic Manuf Plant represented by Mr John Smith, General Manager, Tech Centre.

X_4 = Sony UK Ltd (Bridgend plant), represented by Mr Paul Thomas, Divisional Manager.

X_5 = Corus Packaging Plus (Trostre plant), represented by Mr Mike Rose,

Apprentice Training Manager.

X_6 = Dura UK Ltd, represented by Mr Kevin Collins, Facilities and Maintenance

Manager.

X_7 = Calsonic Kansei Ltd (Technology centre) represented by Mr John Smith, General Manager, Technology Centre.

X_8 = Inco Europe Ltd, represented by Mr Peter Rees, Training and Development Manager.

X_9 = 3M (Gorseinon plant),represented by Mr Richard Davies, Engineering Manager.

Considering each quadrant in turn.

1. Top left-hand quadrant (high business uncertainty /high product complexity).

The companies considered to be operating in this sector were Magstim Ltd, Calsonic Kansei Technology Centre and 3M Ltd (Gorsenion plant).

2. Bottom left-hand quadrant (low business uncertainty /high product complexity)

The companies considered to be operating in this sector were Calsonic Manufacturing Company, Sony (Bridgend plant) and Dura Cables Ltd.

3. Bottom right-hand quadrant (low business uncertainty /low product complexity).

The companies considered to be operating in this sector were Alcoa Ltd (Swansea), Corus (Trostre works, Llanelli) and Inco Ltd.

6.4 Results – overall competencies required.

In order to confirm the relevance of the data being collected each company representative was initially requested to complete some brief demographic details. The purpose of the question was to ascertain the nature of their company’s business and the position of the respondent in that organisation. Each representative was then requested to rate the importance of each broad occupational competence area. To allow for the identification of any trends the representatives were also asked to forecast the importance of the same occupational competencies in 5 years time. The importance of the question is justified in its ability to identify the key areas of competency required by organisations from differing engineering sub-sectors. Averaged across the three organisations within each quadrant the results of the survey are shown in figures 6.2, 6.3 and 6.4.

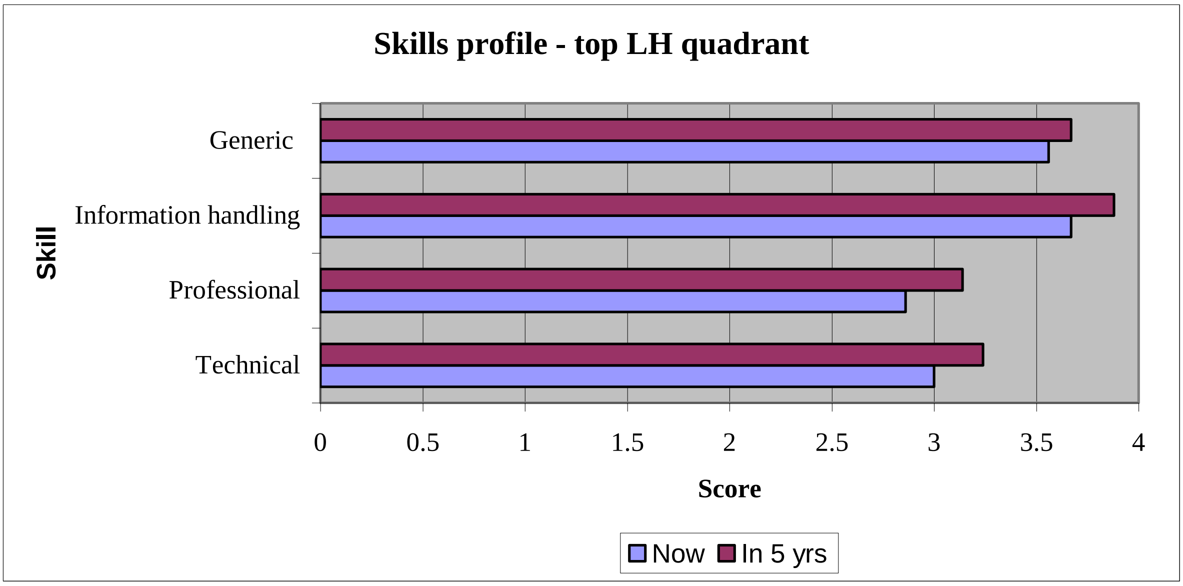

Figure 6.2 Skills profile (top LH quadrant).

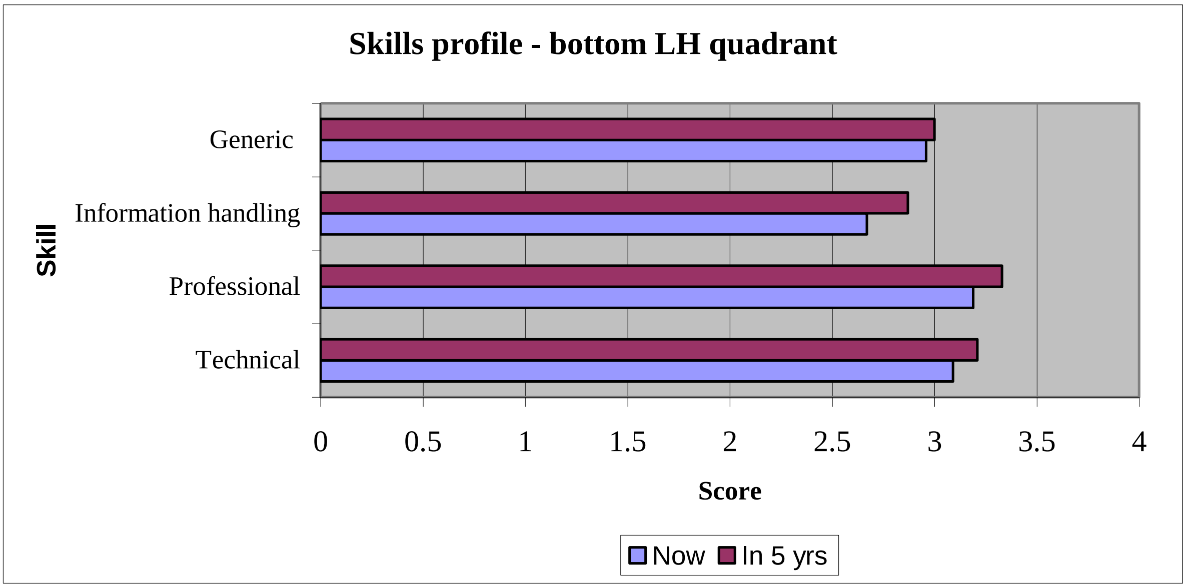

Figure 6.3 Skills profile (bottom LH quadrant).

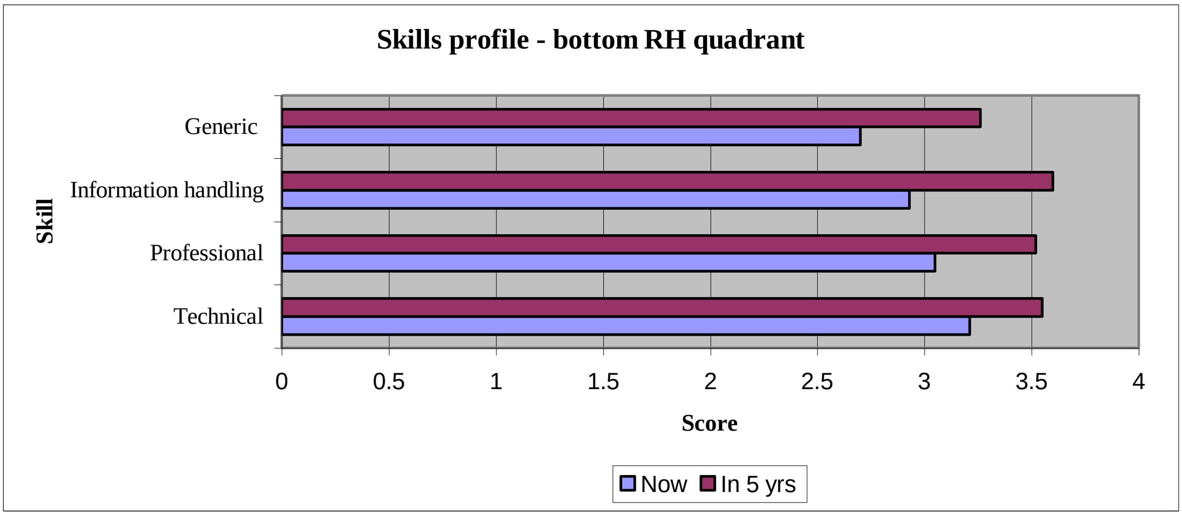

Figure 6.4 Skills profile (bottom RH quadrant).

6.4.1 Results – specific competencies required.

Each specific competence area was subsequently considered in turn with the representatives of each company again being asked to rate the current and anticipated future importance of each specific competency against the following question. "It is important that we establish the current and future competencies required within your company and engineering organisations generally. The following tables list a series of competencies, which you may, or may not, consider as being important. Please tick a number to rate what you consider to be the importance of each competency (1= not important to 4 = very important)". Each skill was referenced against the same marking scale described in chapter 6.2. Thus, the question allowed the representative of each organisation an opportunity to rate individual competencies within each broad category and confirm their relevant importance. It also allowed for an opportunity to cross-reference results against the previous question regarding the rating of each broad competency area. The representatives were also provided with an opportunity to highlight any competencies that were considered to be of importance but were missing from the listing offered to them on the questionnaire

See figures 6.5 - 6.8 for those companies operating within a market of high business uncertainty and high product complexity, figures 6.9 - 6.12 for those companies operating within a market of low business uncertainty and high product complexity and figures 6.13 - 6.16 for those companies operating within a market of low business uncertainty and low product complexity.

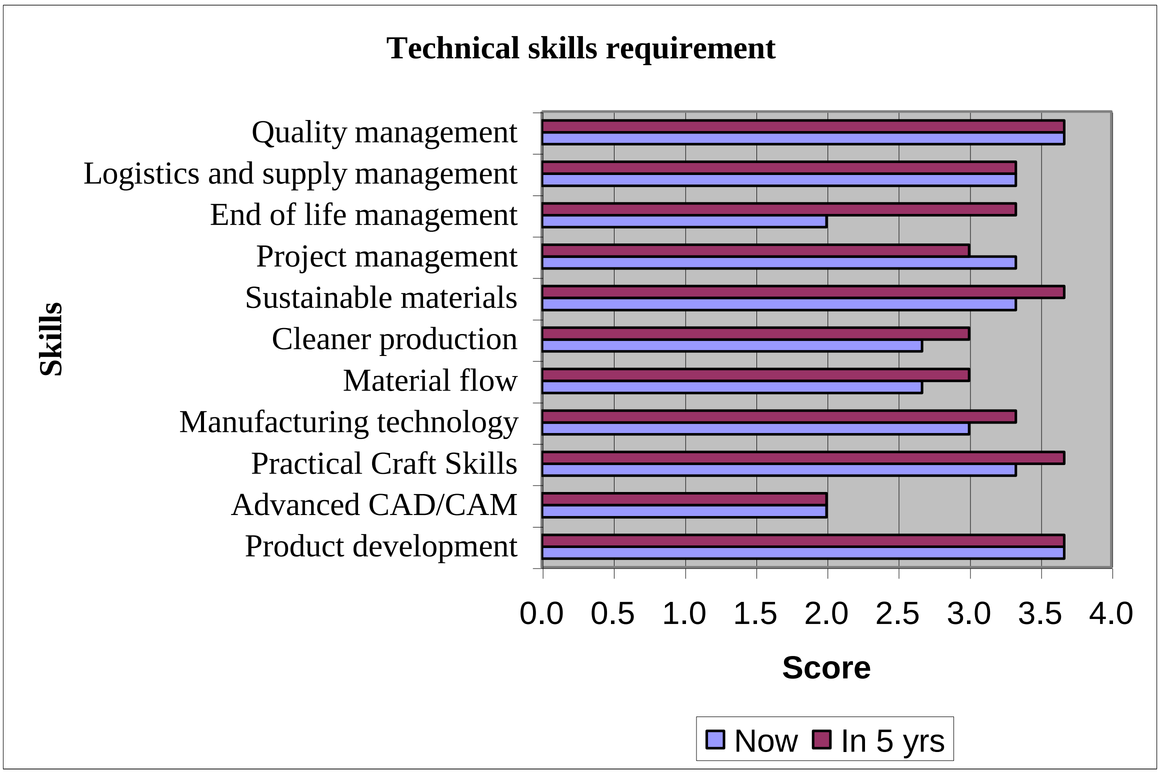

Figure 6.5 Technical skills requirement (top LH quadrant).

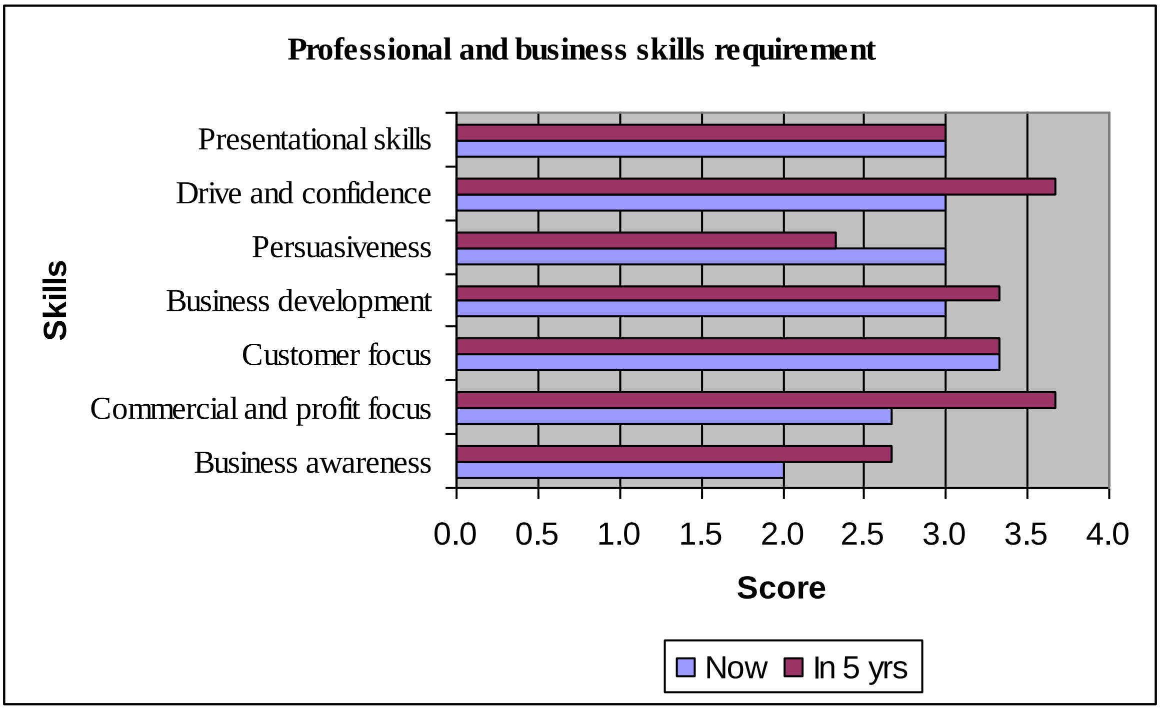

Figure 6.6 Professional and business skills requirement (top LH quadrant).

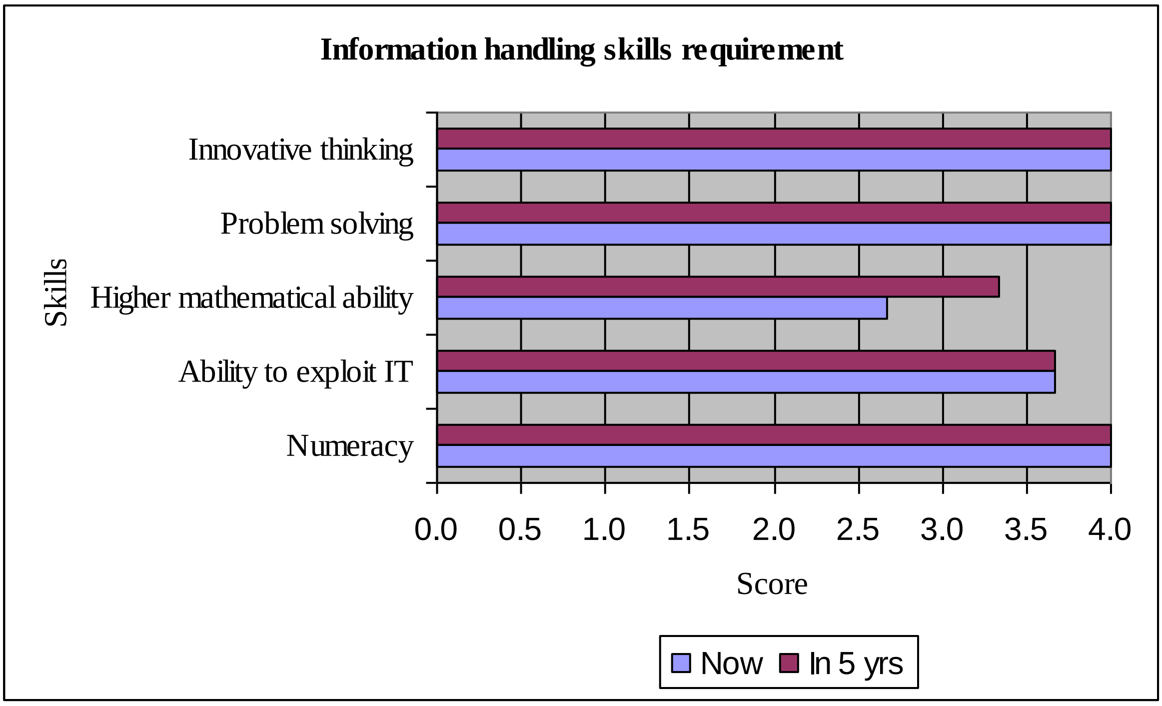

Figure 6.7 Information handling skills requirement (top LH quadrant).

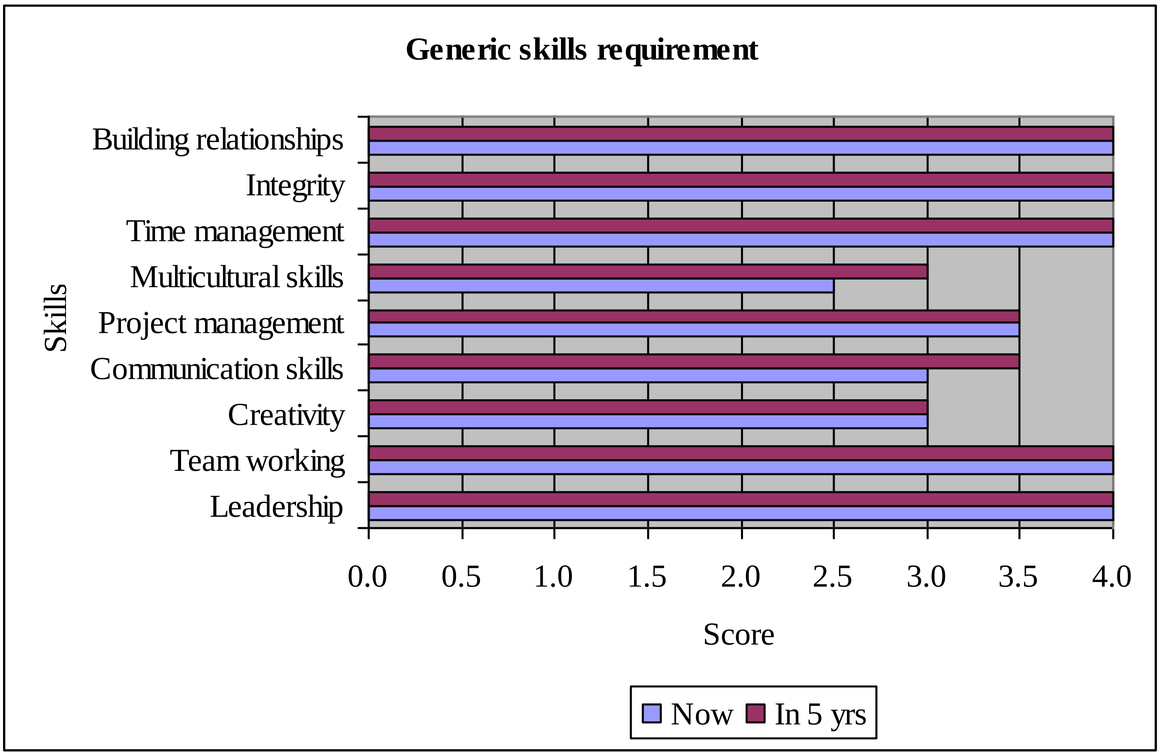

Figure 6.8 Generic skills requirement (top LH quadrant).

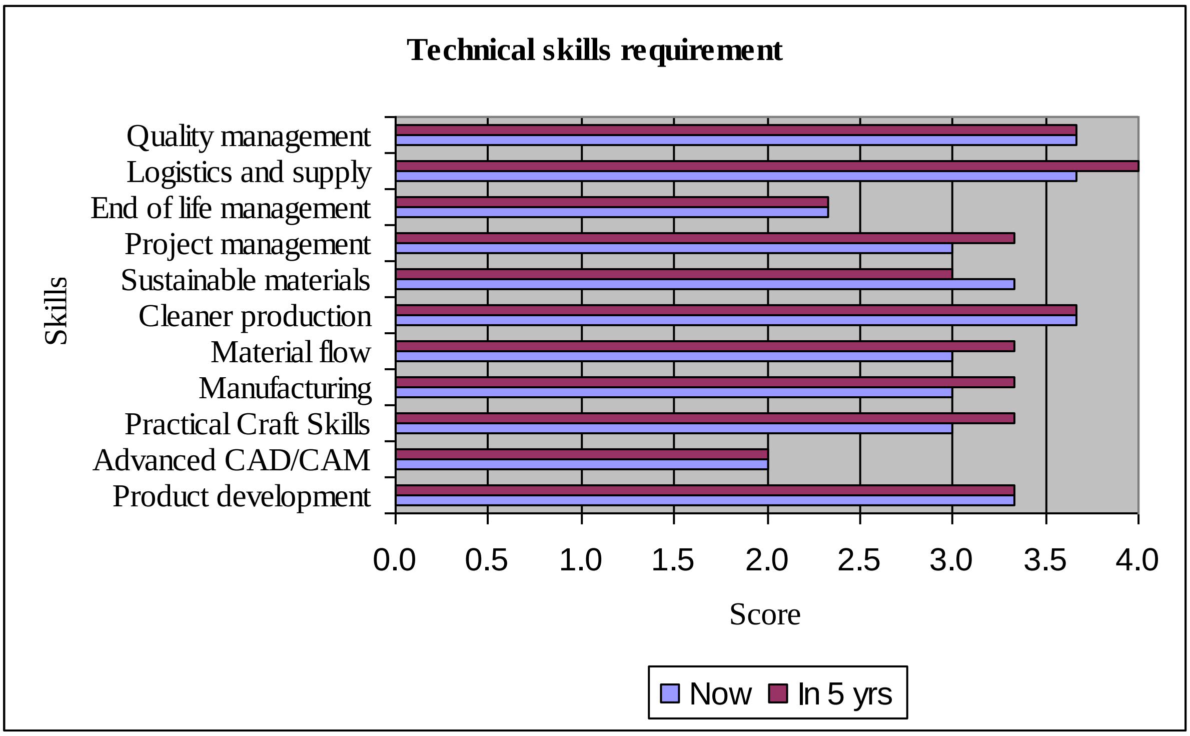

Fig 6.9 Technical skills requirement (bottom LH quadrant).

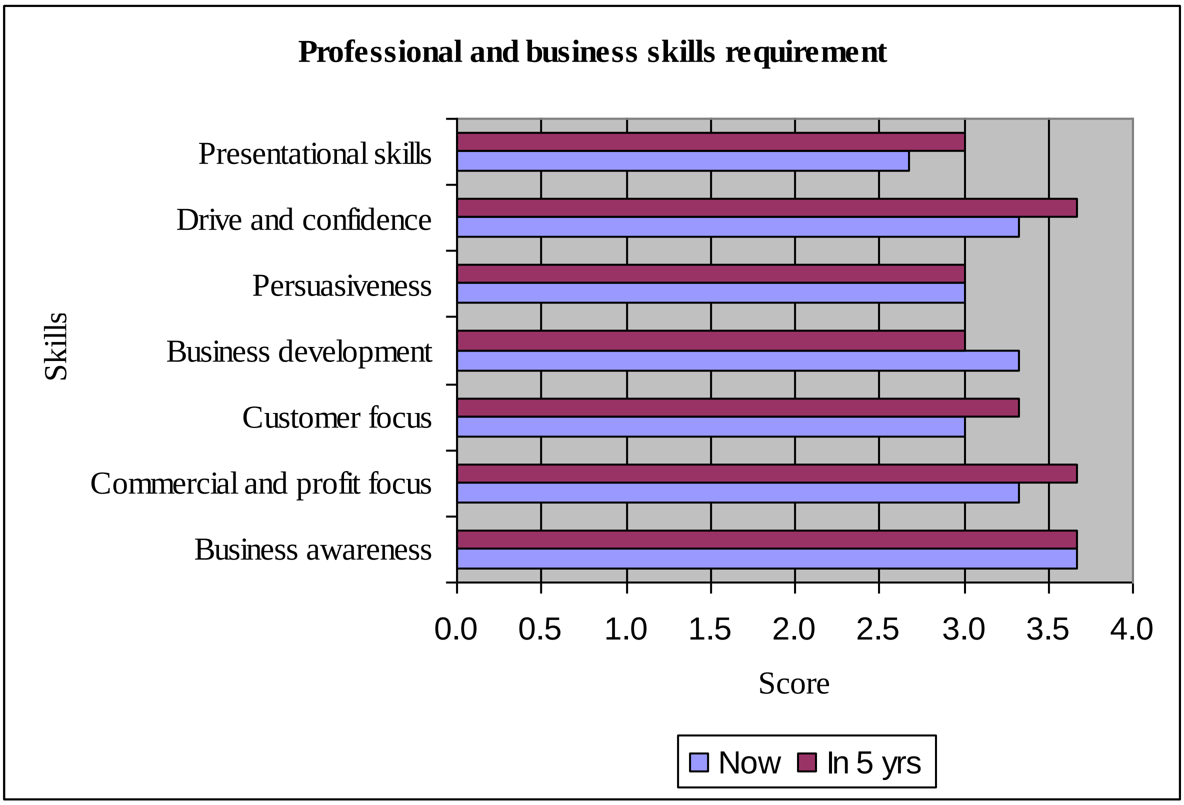

Figure 6.10 Professional and business skills requirement (bottom LH quadrant).

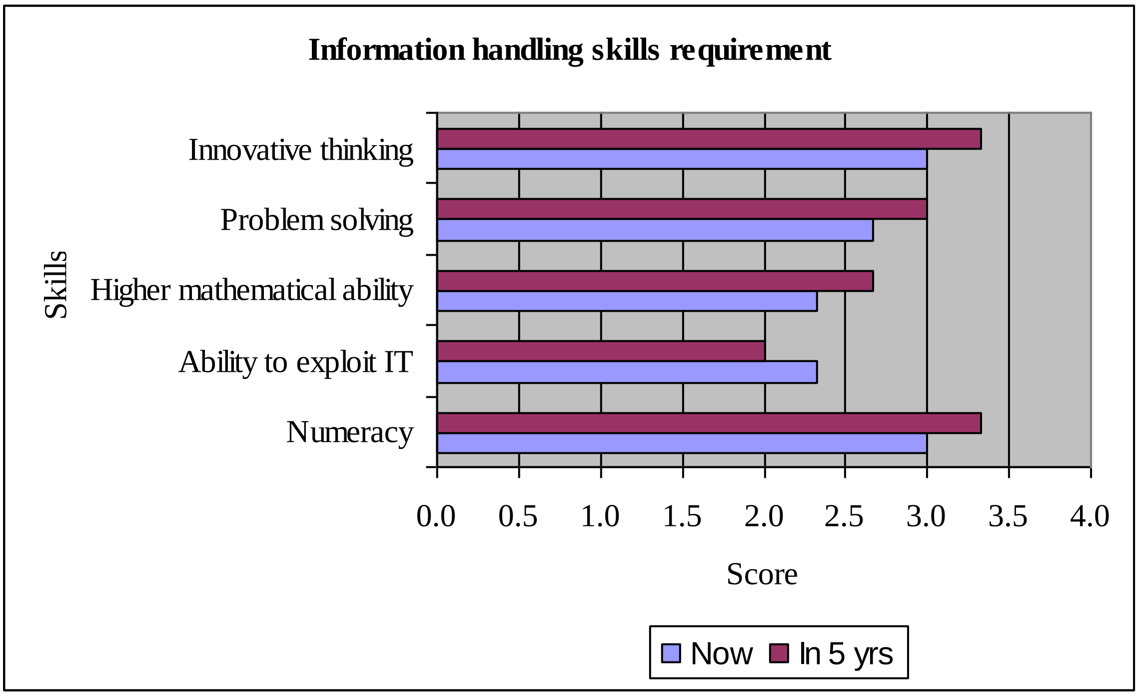

Figure 6.11 Information handling skills requirement (bottom LH quadrant).

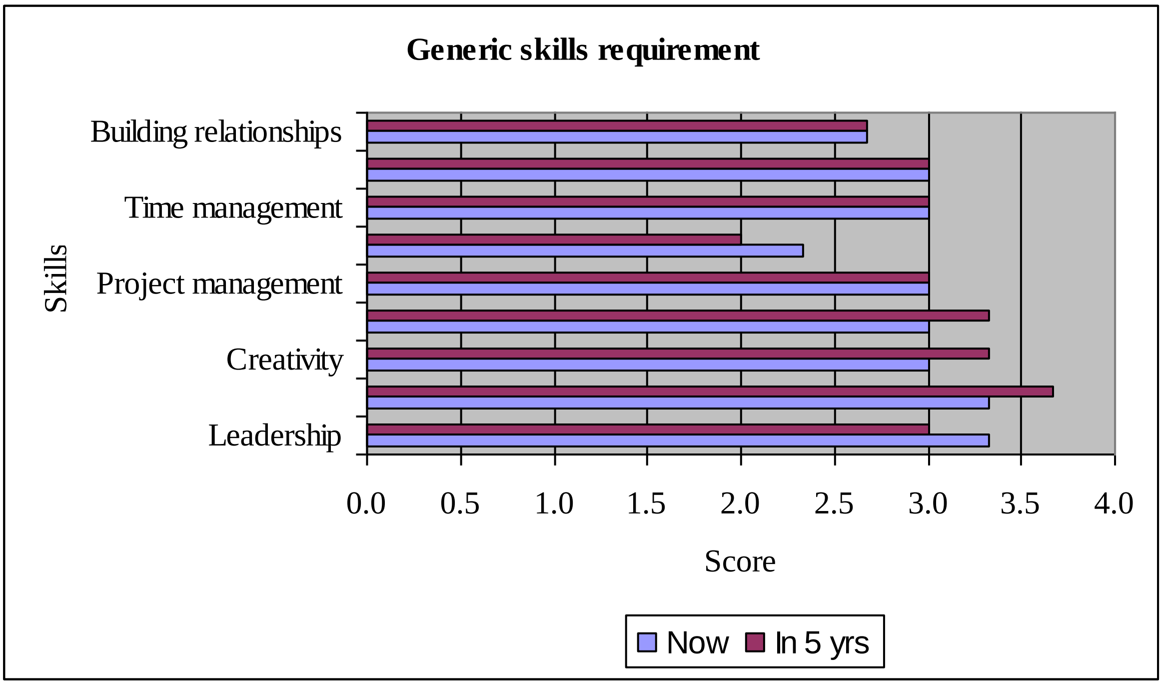

Figure 6.12 Generic skills requirement (bottom LH quadrant).

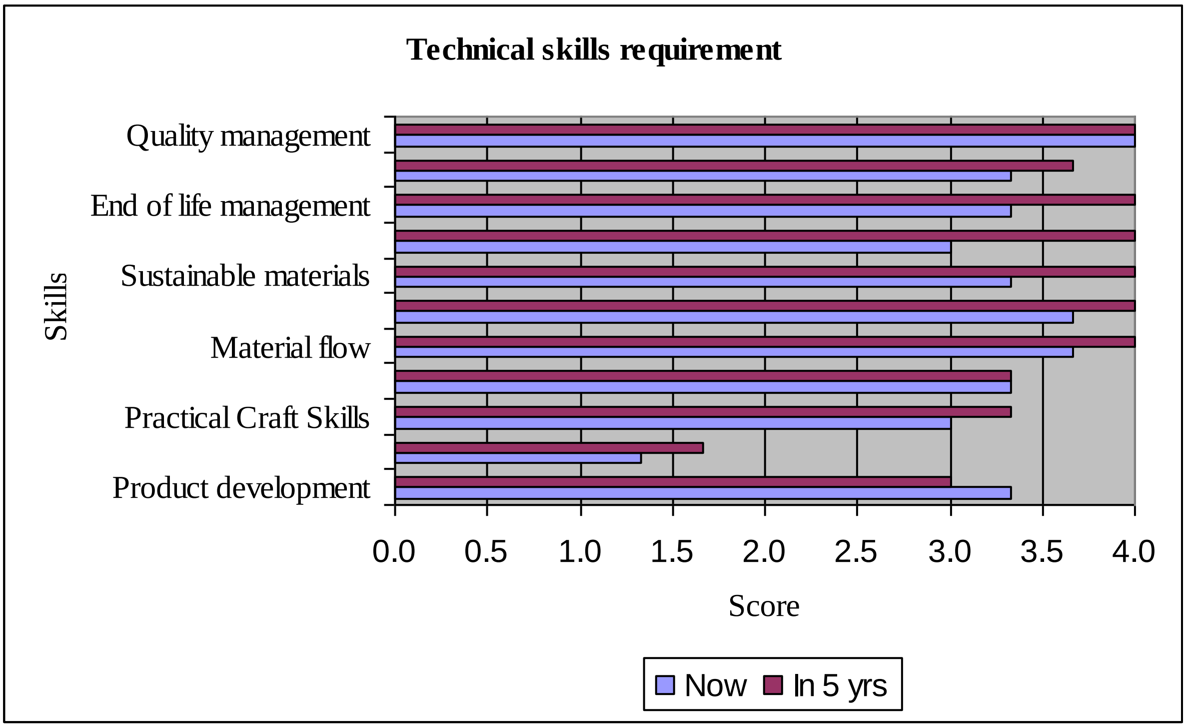

Figure 6.13 Technical skills requirement (bottom RH quadrant).

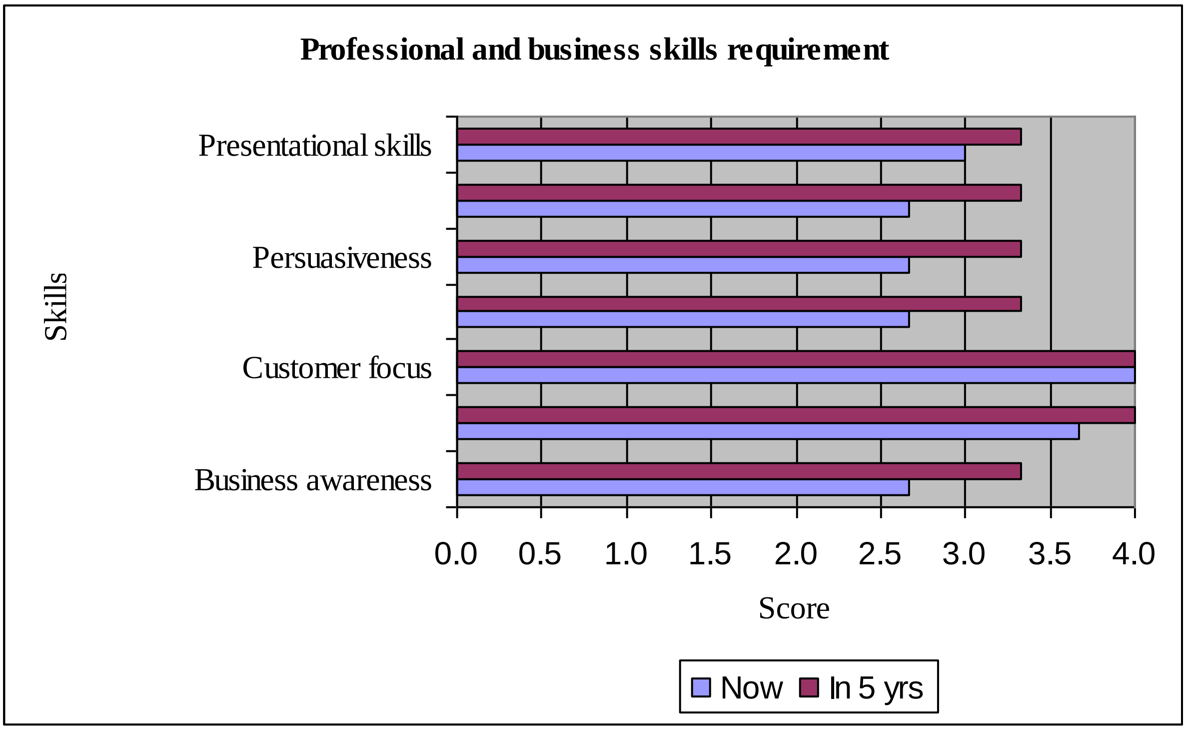

Figure 6.14 Professional and business skills requirement (bottom RH quadrant).

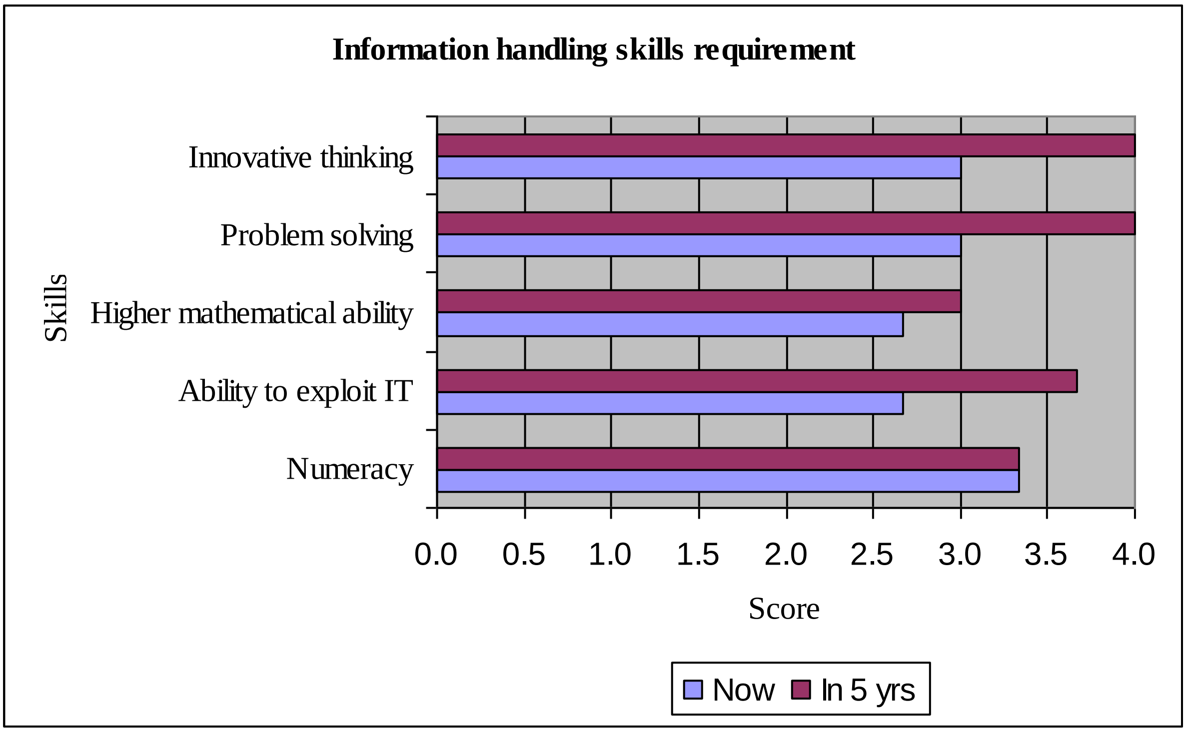

Figure 6.15 Information handling skills requirement (bottom RH quadrant).

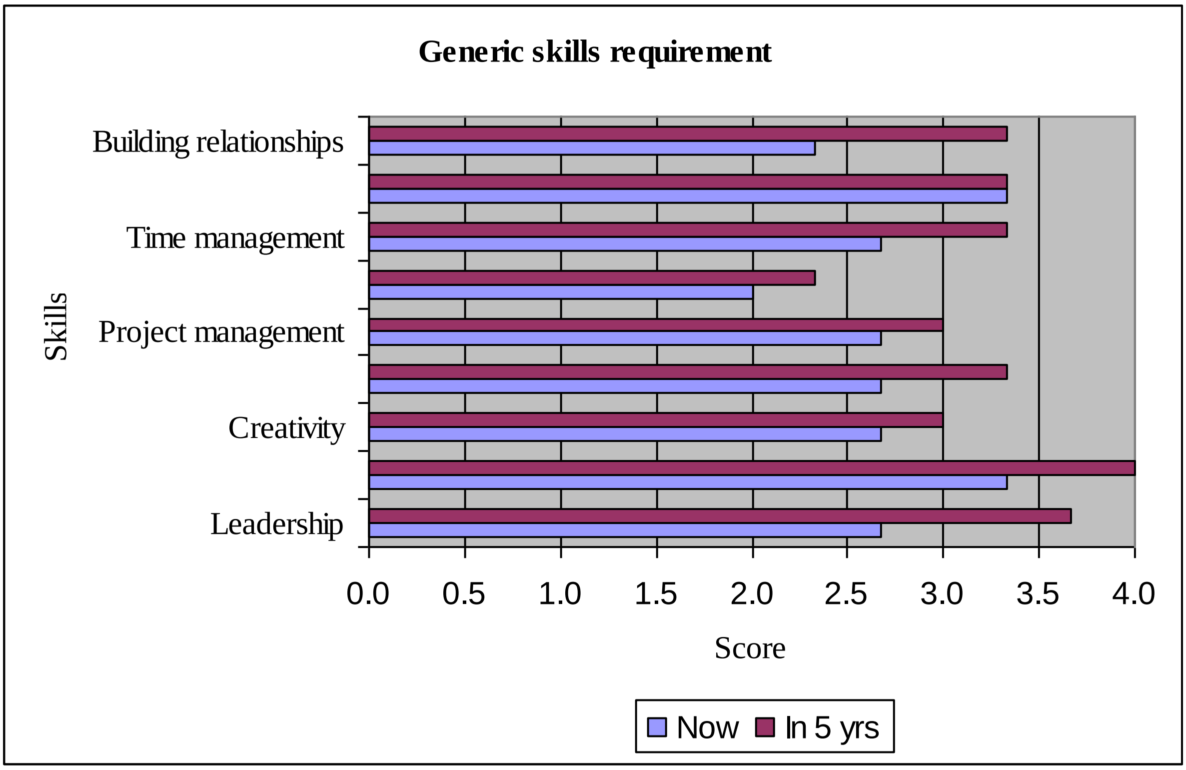

Figure 6.16 Generic skills requirement (bottom RH quadrant).

6.5 Discussion of results.

Initially, each broad competency area was rated for importance. In the case of companies within the top left-hand quadrant of the Puttick grid (where companies operate within a market considered to have high business uncertainty and high product complexity), it was found that the companies participating in the survey (Magstim Ltd, Calsonic Kansei Technology Centre and 3M Ltd) considered that information handling to be the most important competency area flowed by generic skills, technical skills and finally professional skills (see fig 6.2). Forecasting against future importance these companies anticipated a similar competency profile although in all cases the level of competency was noted to increase.

In the case of those organisations working within the bottom left hand quadrant of the Puttick grid (Calsonic Manufacturing Company, Sony (Bridgend Plant) and Dura Cables Ltd), i.e. companies operating with low business uncertainty and high product complexity the most important competency area was considered to be the possession of professional skills followed by technical skills, generic skills and finally information handling skills (see fig 6.3). Again, forecast against future importance, these organisations anticipated a similar competency profile although in all cases the level of competency was again noted to increase.

Finally, in the case of those organisations (Alcoa Ltd, Corus Ltd and Inco Ltd) working within the bottom right hand quadrant of the Puttick grid (low product complexity in markets of low uncertainty) the most important competency area was considered to be the possession of technical skills followed by professional skills, information handling skills and finally generic skills (see fig 6.4). Forecast against future importance these companies anticipated that information handling would become relatively more important although in all cases the level of competency was again noted to increase.

In considering each specific area of competency the profiles for each individual quadrant are broadly consistent with the results from the literature review (chapter 4). For example, in the case of companies operating within a market considered to be characterised by high business uncertainty and high product complexity, then information handling and generic skills such as flexibility, commercial focus, innovative thinking and problem solving abilities would have been expected to be prized. However, it is surprising that technical skills are not rated to a higher level.

This may be due to the fact that many organisations working in this sector are able to recruit technically able and highly qualified staff and then supplement this academic attainment with bespoke company-based training courses.

In the case of companies operating within a market considered to be characterised by low business uncertainty and high product complexity then again the results from the survey compared to the literature review (chapter 4) are considered to be consistent. It can be argued that these organisations require staff with more of an emphasis on professional and technical skills such as design, product development, materials usage, customer focus, drive and confidence. This is justified due to the fact many of these organisations manufacture technically demanding products but often using established technology and are supplying customers with whom they have developed long-term relationships.

Finally, in the case of those companies operating within a market considered to be characterised by low business uncertainty and low product complexity the respondents highlighted the desire for technical and professional skills followed closely by generic and the information handling skills. This is a more diverse profile than that of the other two quadrants of the Puttick grid but the emphasis on professional and technical skills probably reflects the established and traditional nature of the companies involved in the survey.

6.6 Chapter summary.

Specific competencies complementary to the salient economic, technological and occupational drivers of the future have been established. The relative importance of each competency has been tested across a variety of employers and confirmed. The output of this chapter is therefore a quantifiable profile of skills which will be required for each area of engineering activity considered. This data forms the input (the customer requirements) to the QFD product matrix (see chapter 8).

CHAPTER 7

IMPLEMENTATION - DATA GATHERING (STUDENT REQUIREMENTS)

Several issues concerning the provision of learning have been highlighted in previous chapters. In particular it has been established that the final curriculum proposal will need to ensure it contributes to the personal development of the learner as well as the industrial performance of the employer. This chapter is used to present the results of two student surveys conducted to establish student requirements.

The first was a general survey used to investigate:

- The preferred learning and assessment methods of the students.
- The professional and personal aspirations of the students and the level of correlation between student and employer expectations.
- Recruitment issues.

The second survey was used to investigate the preferred learning styles of the students.

The output of this chapter is a profile of student requirements for the finalised curriculum proposal. In conjunction with the employer requirements this data forms an input (the student requirements) into the QFD product matrix (see chapter 8).

7.1 Data collection method - general survey.

Individual cohorts of students were asked to complete the general questionnaire under the supervision of the researcher. This method allowed for any questions or queries to be clarified and furthermore it provided for an opportunity to explain the aims and objectives of the research and answer any concerns about the confidentiality of the data. The data was collected from 16-18 year old engineering students based at Coleg Sir Gâr with a total number of 70 students completing the standard student questionnaire (this representing a return of 93% of the entire cohort). Respondents comprised students from the National Certificate in Electrical and Electronic Engineering, National Certificate in Mechanical Engineering, National Diploma in Electrical and Electronic Engineering and National Diploma in manufacturing courses. Employed apprentices on the National Certificate courses were identified and considered as a separate cohort for analysis. The breakdown of students per course was as listed below.

(i) National Certificates, Electrical Engineering and Mechanical Engineering – 41 students.

(ii) National Diplomas, Manufacturing Engineering and Electrical Engineering – 29 students.

(iii) Modern Apprentices – 28 students.

7.1.1 Results - preferred learning and assessment methods.

In light of the literature search described in chapter 5 a range of commonly used learning and assessment methods were presented to the students and they were asked to indicate their preferred methods. The purpose of the research was two-fold. Primarily, it was used to ascertain the preferred methods of learning and assessment of the students (for subsequent inclusion within the QFD matrices). Secondly, it provided an opportunity to cross-reference the results to the learning styles survey (thus providing further evidence of the requirements of the students). No scoring system was employed and no limit on the number of selections was placed on the student. The results are presented as a percentage and are shown in figures 7.1 and 7.2.

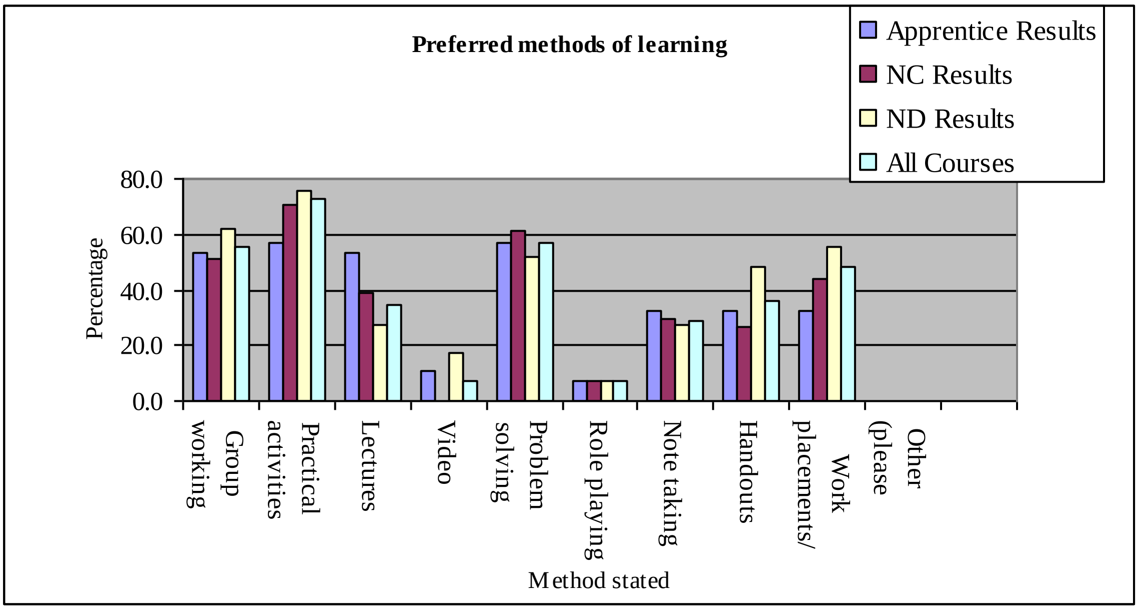

Figure 7.1 Preferred methods of learning.

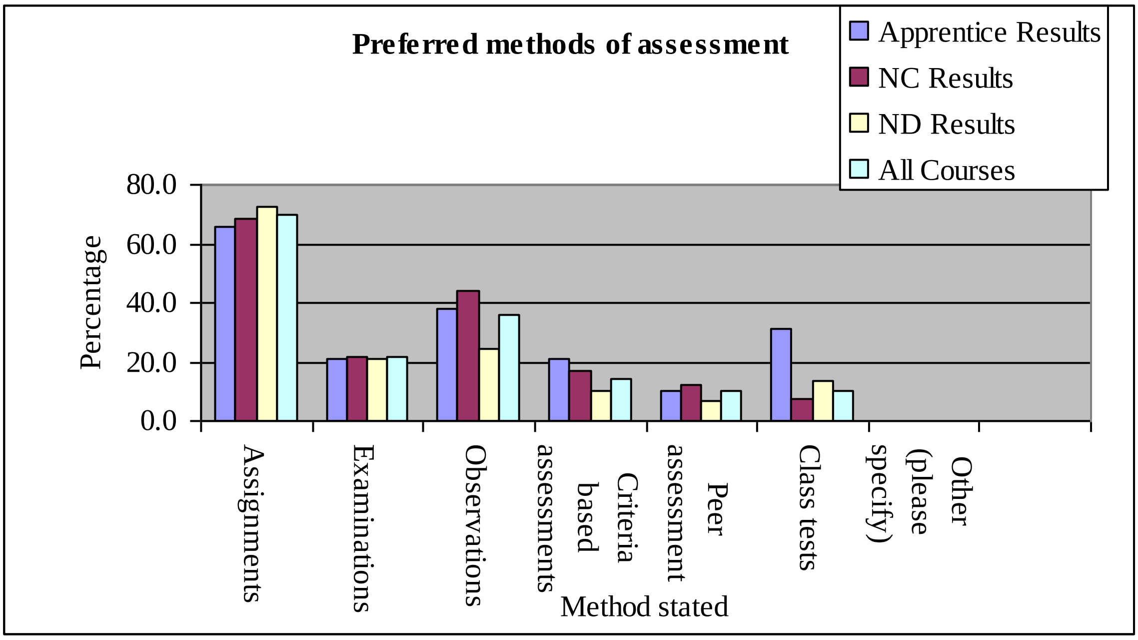

Figure 7.2 Preferred methods of assessment.

In order of preference the learning methods were identified as being: practical activities, problem solving, work placements, group working and then lectures. To enable practical use of these results within the QFD curriculum matrix the results are weighted to reflect their relative importance. The remaining learning methods considered in the survey have been omitted. In order of preference the assessment methods were identified as being: assignment, observations and class tests. Again on entry to the QFD curriculum matrix the results are weighted to reflect their relative importance. The remaining assessment methods considered in the survey have been omitted.

7.1.2 Results - professional and personal aspirations.

The relative importance of key areas of competency were previously tested in the employer survey (see chapter 6). To determine the level of correlation between employer and student expectations, each student was also requested to rate the importance of each broad occupational competence area. To allow for the identification of any perceived trends the students were also asked to forecast the importance of the same occupational competencies in 5 years time. The same scoring system as used in the employer survey was employed (see chapter 6.2). The purpose of this research was to determine any discrepancies between employer and students expectations (and thus any possible negative impact on student motivation and performance). The results are shown in figures 7.3 and 7.4

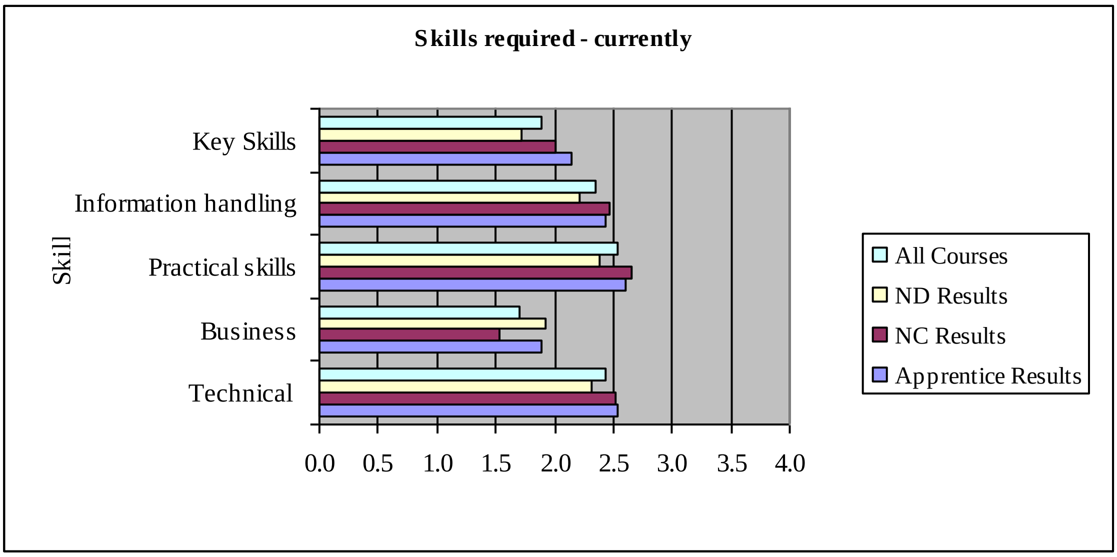

Figure 7.3 Skills required currently.

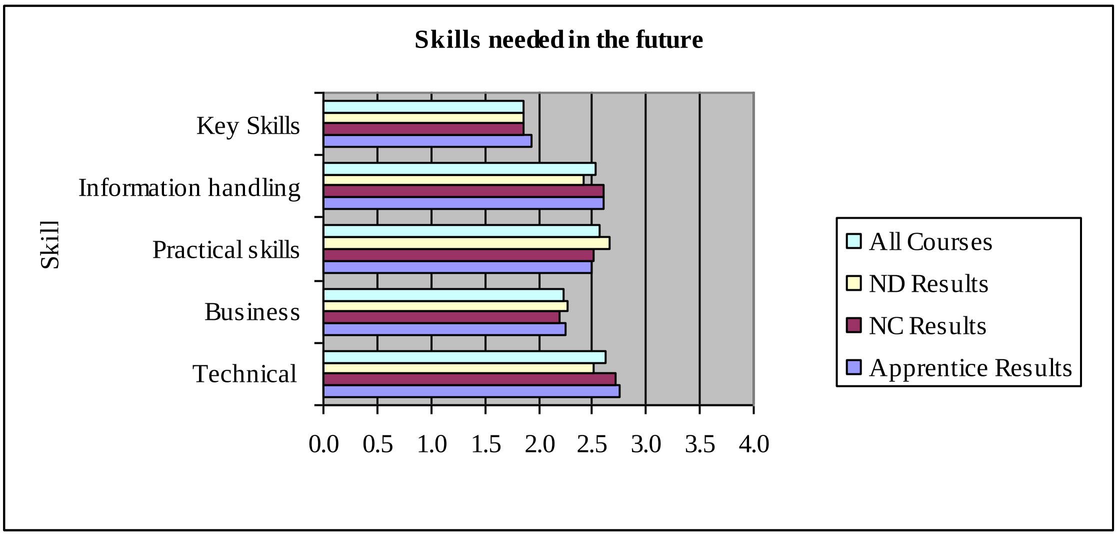

Figure 7.4 Skills required in the future.

Students were subsequently asked to indicate how far they intended to pursue a career in engineering. In particular they were asked to select what they anticipated to be their long-term goals in terms of professional and academic achievement. The purpose of this research was to two-fold. Firstly, it was used to determine any potential inconsistencies between student and employer expectations. Secondly, it was anticipated that the design of the final curriculum proposal could be augmented by the selection of suitable learning and assessment methods and thus ensure that students are provided with opportunities to progress to higher levels of achievement within each respective domain of learning. No scoring system was employed and the results are presented as a percentage. The results are shown in figures 7.5 and 7.6

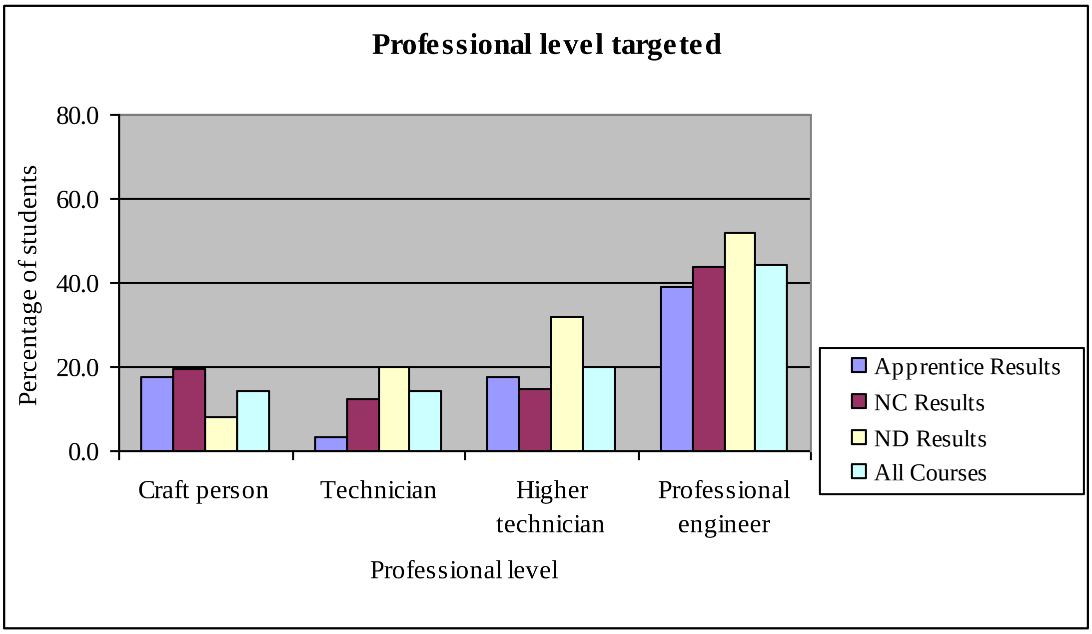

Figure 7.5 Targeted professional levels.

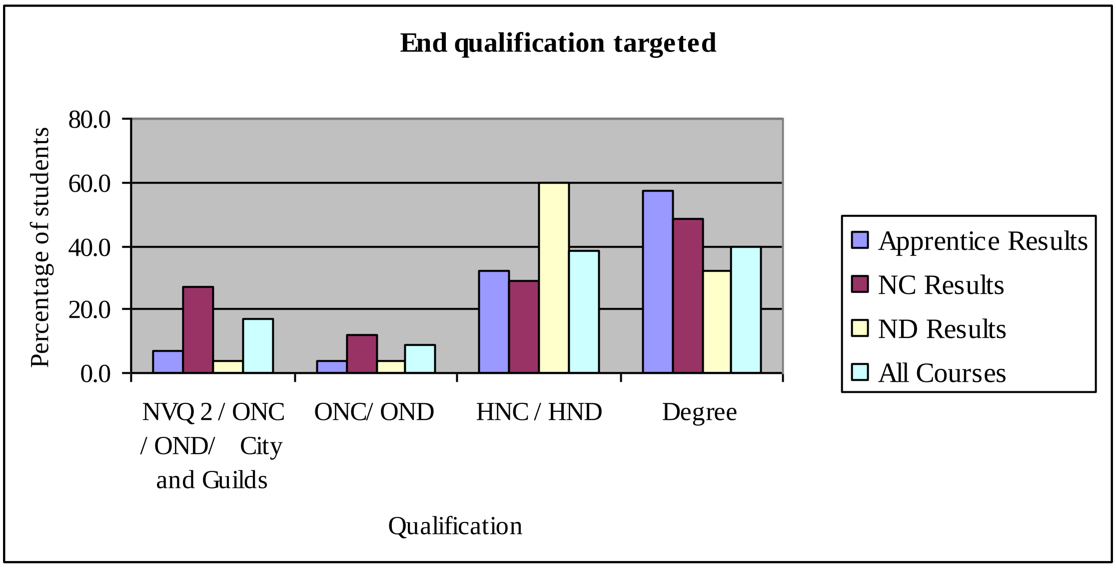

Figure 7.6 Targeted qualification levels.

7.1.3 Results - recruitment issues.

The purpose of the survey was not to complete an in-depth review of recruitment related issues. Instead, the survey was intended to provide for an opportunity for identifying which factors impacted upon students in their decision to pursue a career in engineering. It was anticipated that the input to the QFD matrices (the customer requirements) would be enhanced to reflect these issues of importance to the students. Similarly, by identifying any recruitment difficulties it was again anticipated that the QFD matrices be used in attempting to address these problems. With regard to the student questionnaire it was decided to investigate:

- Student perceptions of engineering, the role of engineers (see figures 7.7 and 7.8) and the reasons the students decided upon engineering as career path (see figure 7.9).
- Recommendation levels and reasons for recommending engineering as a career (see figure 7.10 and 7.11).

- Which subjects the students have found of greatest interest (see figure 7.12).

7.1.3.1 Results - student perceptions of engineering.

Firstly, reasons for initial recruitment were investigated and the students were asked about their perceptions of engineering and engineers. Three questions were asked as follows.

Question 1 - How much do you agree or disagree with the following statements about engineering?

Question 2 - The following statements can be used to describe engineers. How much do you agree or disagree with them?

Question 3 - Please state the main reasons why you decided to take up engineering as a career.

In answering questions 1 and 2 the students were asked to rate their answers using the same scoring system as used in the employer survey (see chapter 6.2). The results are shown in figures 7.7 and 7.8. In answering question 3 students were presented with a range of possible reasons for entering engineering and asked to reflect upon each reason and indicate which were applicable in their individual case. No limit was set on the number of options selected and results are presented as a percentage. The results are shown in figure 7.9

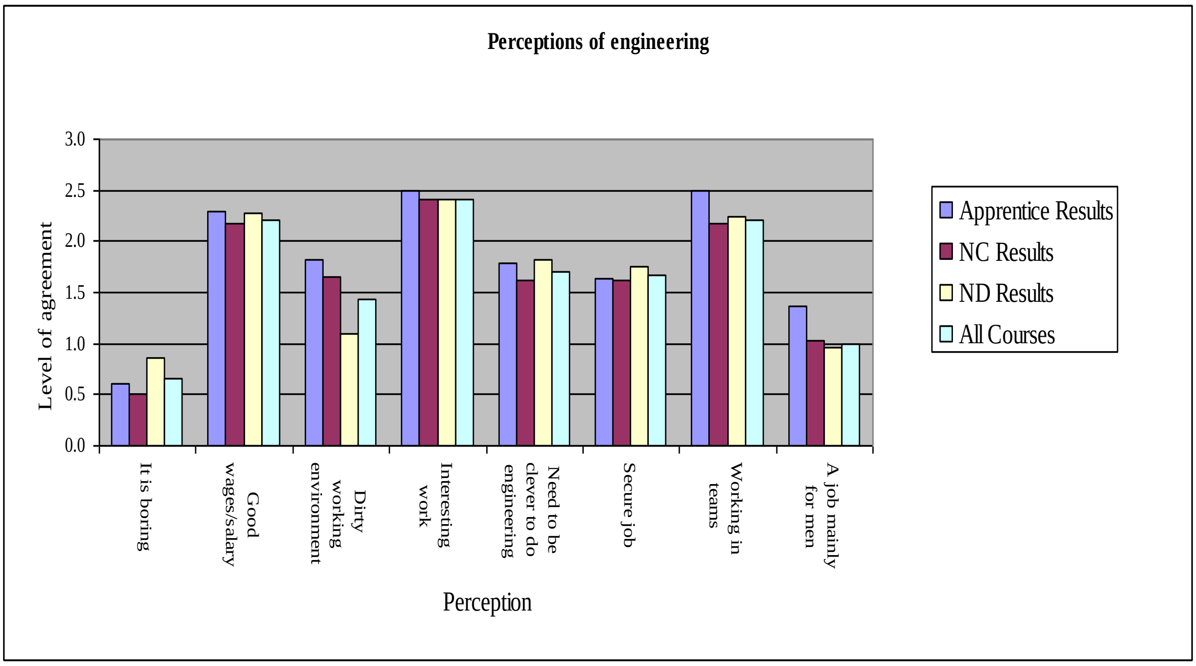

Figure 7.7 Perceptions of engineering.

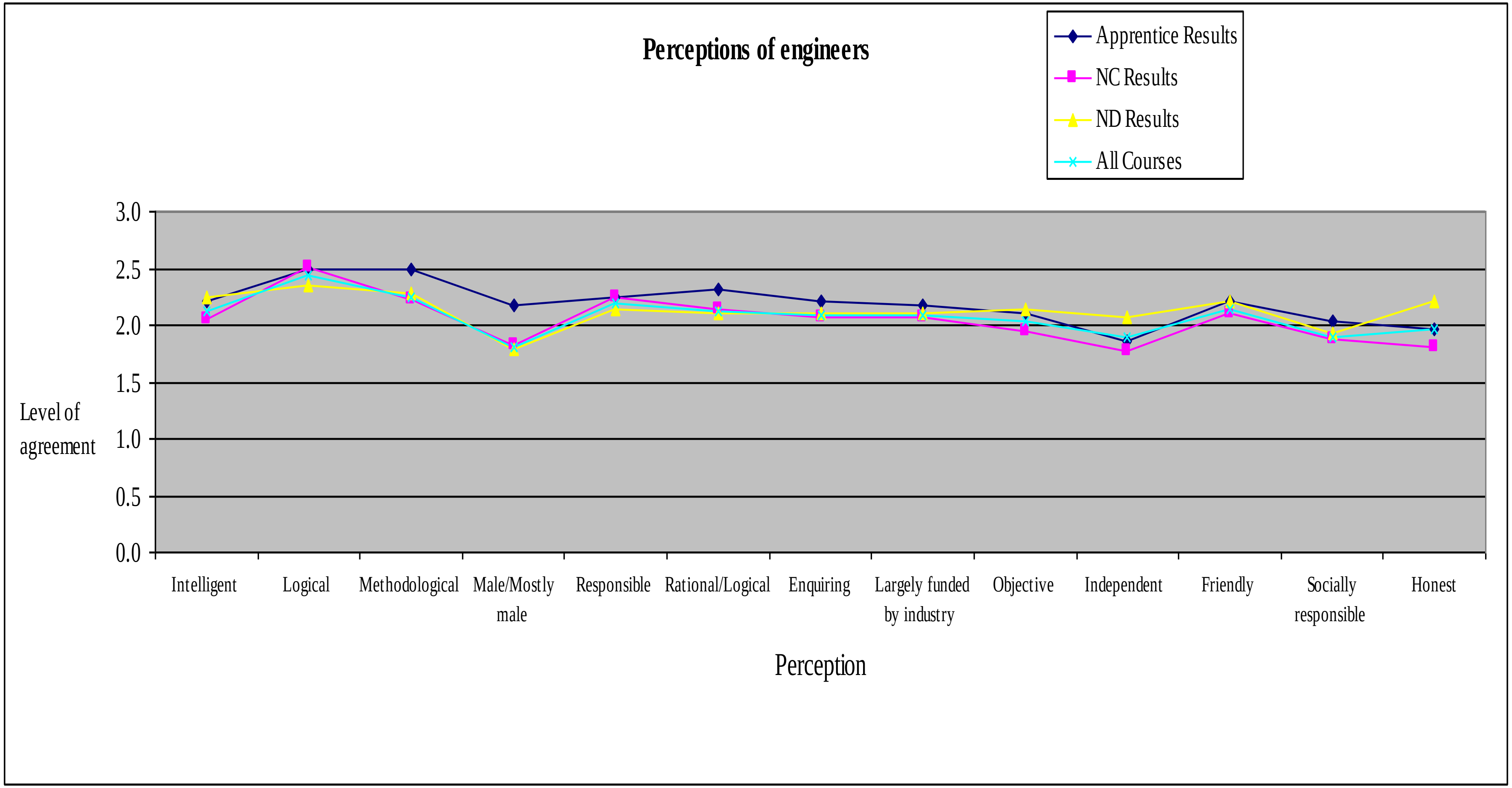

Figure 7.8 Perceptions of engineers.

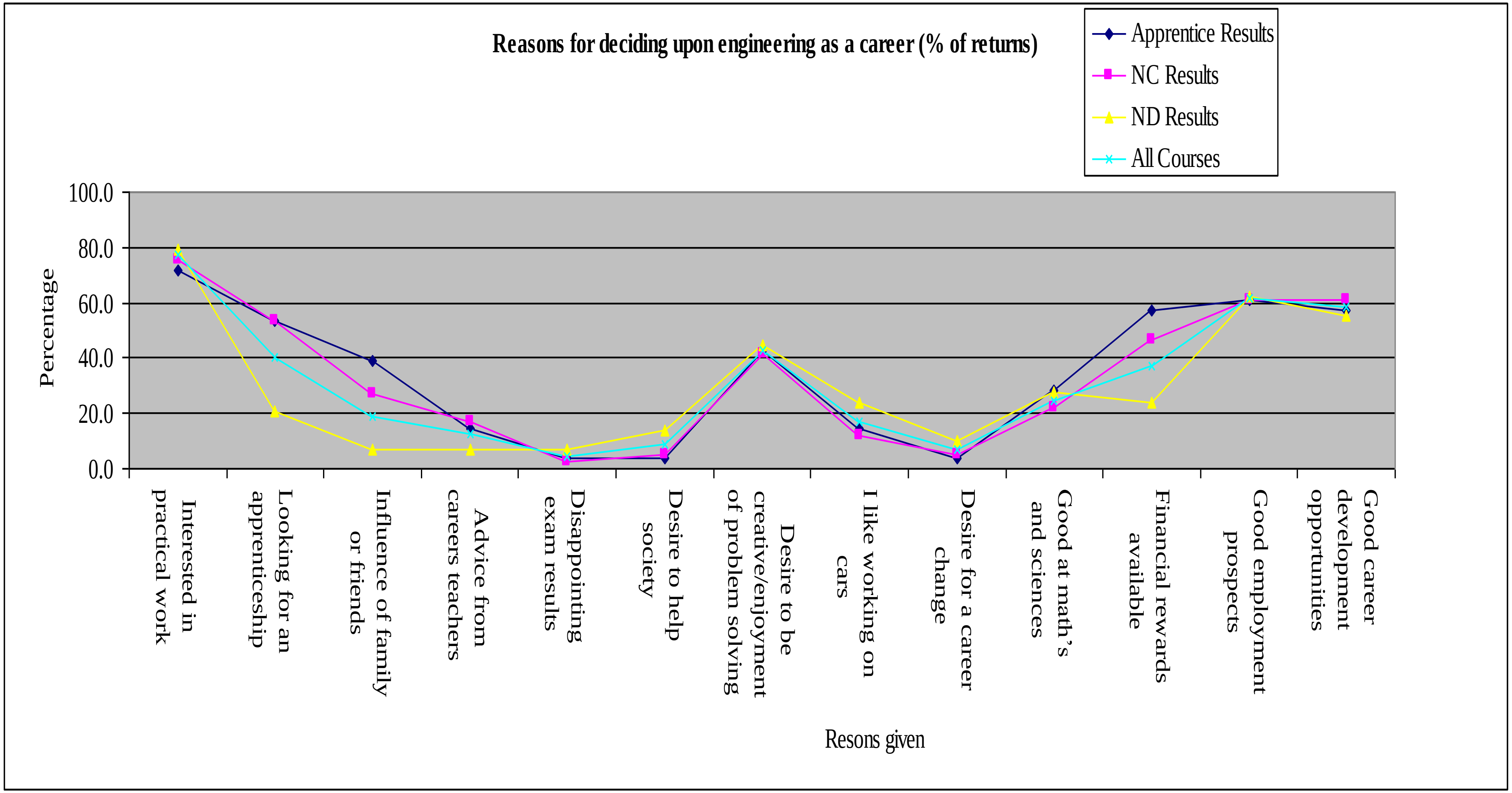

Fig 7.9 Stated reasons for deciding upon engineering as a career.

7.1.3.2 Results - student satisfaction levels.

Students were asked to reflect on their actual experiences of studying engineering. The purpose of this research was to confirm the level of satisfaction students had with their engineering studies. Secondly, students were asked to confirm if they would recommend engineering as a profession to other students and (if applicable) provide reasons for this recommendation. Two questions were therefore asked as follows.

Question 1 - Would you recommend engineering as a career?

Question 2 - Please indicate the main reasons why you would recommend engineering as a career.

In answering the first question students were presented with three possible answers (yes, no or don't know). Students were asked to reflect on each and indicate which was applicable in their individual case. The results are presented as a percentage and shown in figure 7.10

In answering the second question students were presented with a range of possible reasons for recommending engineering as a career path. Students were asked to reflect on each reason and indicate which were applicable in their individual case. No limit was set on the number of options selected and the results are presented as a simple percentage. The results are shown in figure 7.11

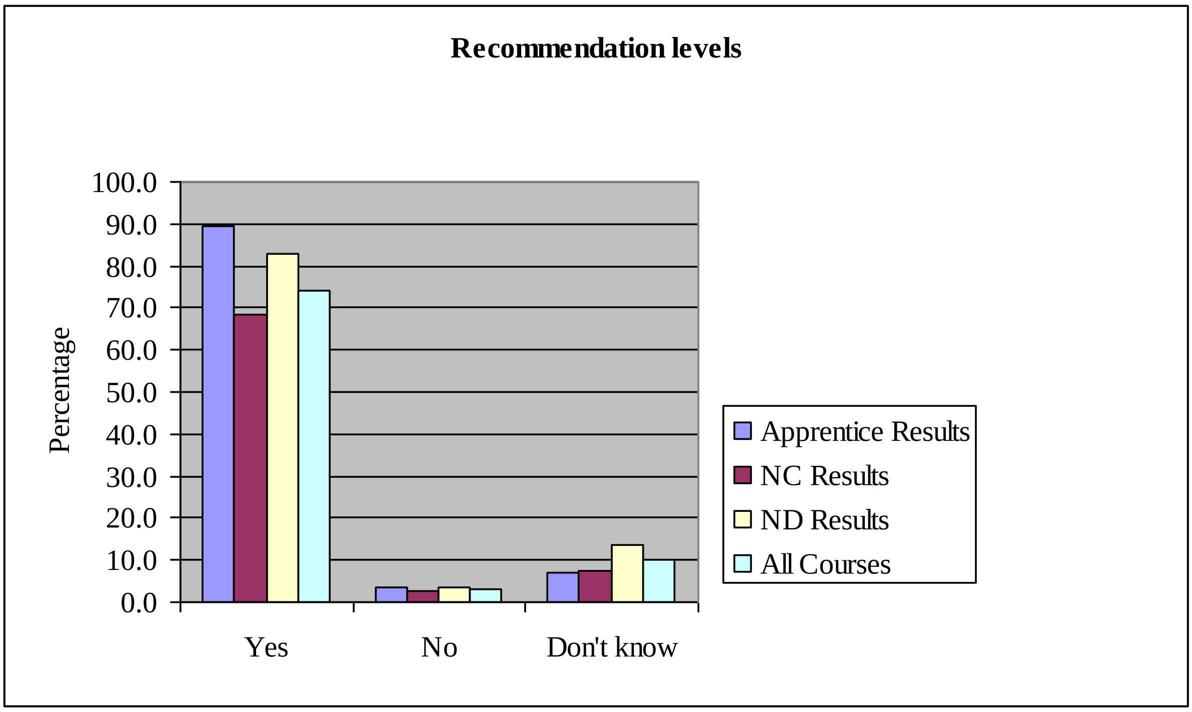

Figure 7.10 Recommendation levels for engineering as a career.

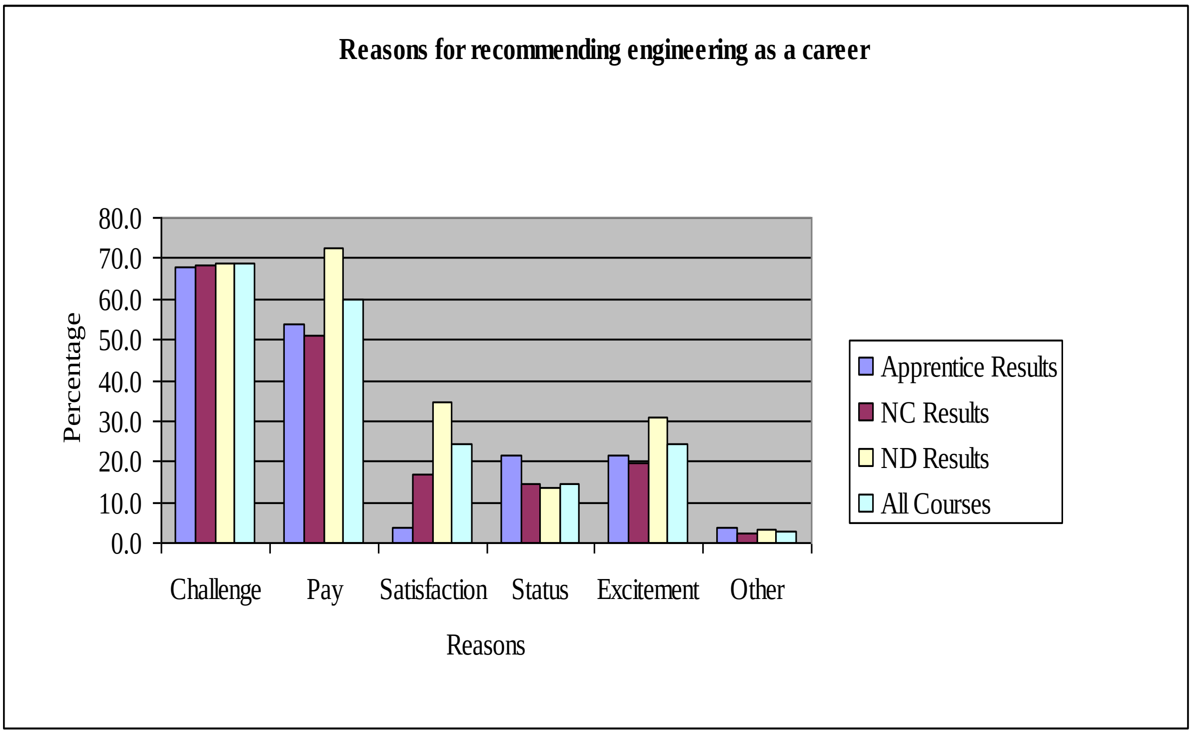

Figure 7.11 Reasons for recommending engineering as a career.

7.1.3.3 Results - study areas of greatest interest.

Students were asked to reflect on their experiences of studying engineering and indicate which subject areas they had found of greatest interest. Specifically the following question was asked.

Question 1 - What areas of your current programme of study have you found of greatest interest?

This question was included in the survey in an attempt to identify areas of interest and value to the student and with a view to their possible inclusion within the final curriculum proposal.

In answering this question, students were presented with a range of possible areas of study, asked to reflect on each option and indicate which were applicable in their individual case. No limit was set on the number of options selected and the results are again presented as a percentage. The results are shown in figure 7.12

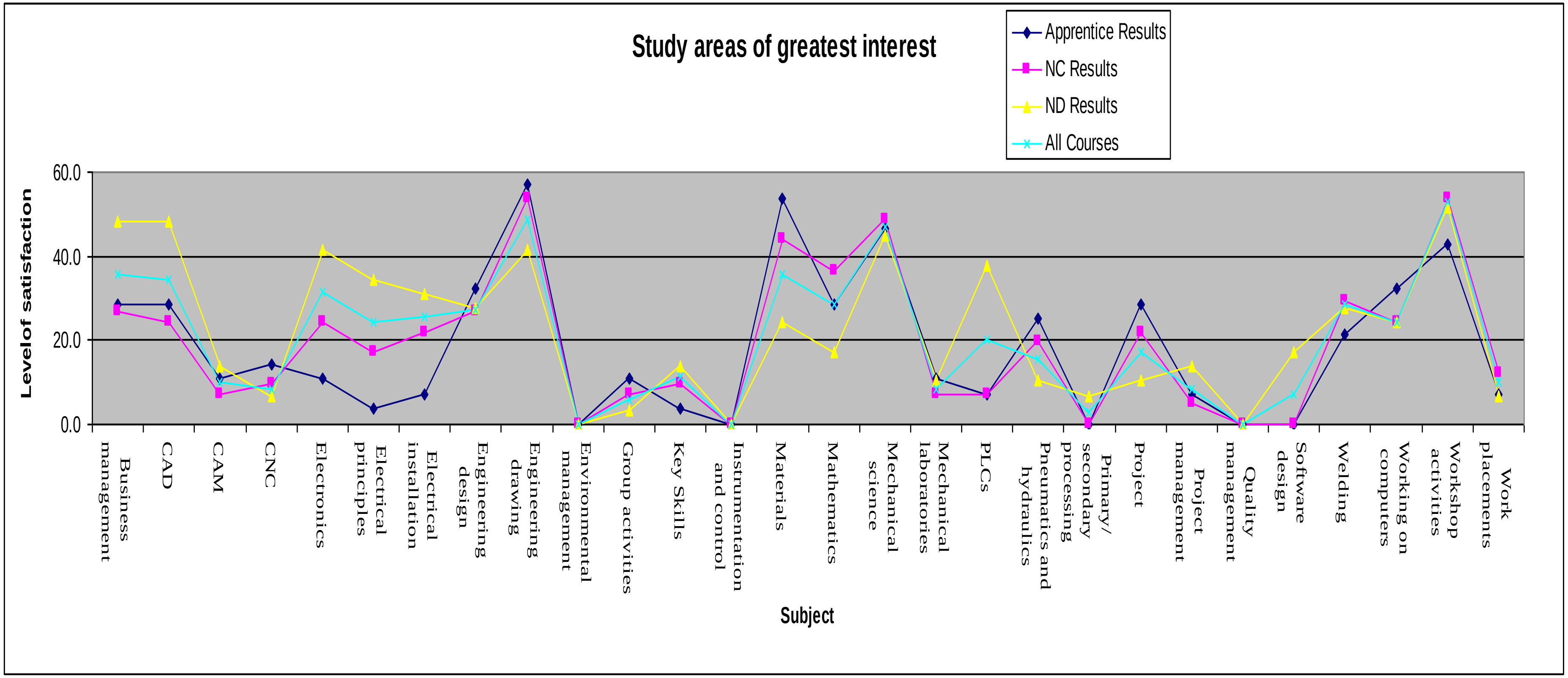

Figure 7.12 Study areas of greatest interest.

7.2 Results - survey of preferred learning styles.

The data was again collected from 16-18 year old engineering students based at Coleg Sir Gâr with a total number of 70 students completing the standard student questionnaire. The average scores for the entire cohort were calculated and the predominant learning styles ascertained, see table 7(i).

Activist	Reflector	Theorist	Pragmatist	
20	20	20	20	Very strong preference
19				
18		19	19	
17				
16	19	18	18	
15				
14		17		
13	18	16	17	
12	17	15	16	Strong preference
	16			
11	15	14	15	
10	14	13	14	Moderate preference
9				
8	13	12	13	
7	12	11	12	
6	11	10	11	Low preference
5	10	9	10	
4	9	8	9	
3	8	7	8	Very low preference
	7	6	7	
2	6	5	6	
	5	4	5	
	4	3	4	
	3	2	3	
1	2	1	2	
	1		1	
0	0	0	0	

Table 7(i) Results of learning styles investigation.

In order of preference the learning styles identified were: activist (strong preference), pragmatist (moderate preference), reflector (moderate preference) and theorist (moderate preference). It should be noted that the results represent an average score from the entire student cohort and results from individual students were not considered. To enable practical use of these results within the QFD curriculum matrix the average score results were used and weighted to reflect their relative importance.

7.3 Chapter summary.

The final curriculum proposal must be developed in a complementary and sensitive manner to the learning requirements of the students. This chapter was used to describe and present the results of two student surveys which were conducted to ascertain these requirements. Four areas of research were identified and the salient results were as follows.

(i) Preferred learning and assessment methods of the students.

The preferred learning methods were identified as being practical activities, problem solving, work placements, group working and then lectures. The preferred assessment methods were identified as being assignment, observations and class tests.

(ii) Professional and personal aspirations.

In anticipating which competency areas are currently of importance the students identified (in order of priority) practical skills, information handling and the use of technical skills. The need for business skills and key skills (generic skills) was considered to be low in comparison. When asked to rate the importance of the same competency areas in the future the students produced a broadly similar set of results. Targeted professional and academic attainment are commensurate and would suggest that the curriculum proposal should allow for suitable learning and assessment methods to ensure that students are provided with opportunities to progress to higher levels of achievement.

(iii) Recruitment issues.

In relation to the cohort of students involved in the survey, the perception of engineering and the role of engineers have been investigated. In addition, individual reasons for pursuing engineering as a career, satisfaction levels with current awards, and the identification of which learning modules they have found of greatest benefit have been established.

(iv) Preferred learning styles.

In relation to the students participating in the survey the preferred learning style combination were established as being activist/pragmatist.

In conjunction with a review of relevant learning and curriculum modeling theory (see chapter 5) the data (student requirements) from (i) and (iv) will be input into the QFD curriculum matrix. The results from (ii) and (iii) are used to augment and improve the final curriculum proposal (see chapter 8).

CHAPTER 8

IMPLEMENTATION - DATA ANALYSIS

The research methodology as described in chapter 3.2 has been implemented and the requirements of both main customer groups (employers and students) have been determined.

This chapter is where synthesis of the data is achieved and the method employed is the application of a two-phase application of Quality Function Deployment.

At the beginning of the chapter an explanation of the two-phase application of Quality Function Deployment is provided. Using the results of chapter six a product matrix which prioritises employer requirements is then established for each active quadrant of the Puttick grid. The output from each matrix is the determination of which teaching modules are best suited to deliver the critical competencies required. The output from each product matrix is subsequently integrated into a curriculum matrix which identifies and prioritises the teaching and assessment methods commensurate to the perspective of learning and the student learning requirements.

The output of this chapter is the identification of a curriculum profile which is an accurate translation of customer demands into deliverable curriculum characteristics.

8.1 Introduction to chapter.

As shown in figure 8.1 a two-phase application of QFD was proposed. It was envisaged that a product matrix be initially developed with the input to the matrix being prioritized competencies (based on the salient drivers of change impacting on engineering employers). The output of the product matrix being the identification of teaching modules best suited to deliver the critical competencies required. Subsequently, a second matrix – termed the curriculum matrix is developed. The purpose of the curriculum matrix is to allow for the construction of the final curriculum proposal which is not only complementary to the requirements of engineering employers but also robust to external constraints and a range of possible future business scenarios. In recognition of the importance of the students as customers the curriculum matrix is used to ensure that complementary learning, teaching and assessment strategies are incorporated in the final curriculum proposal.

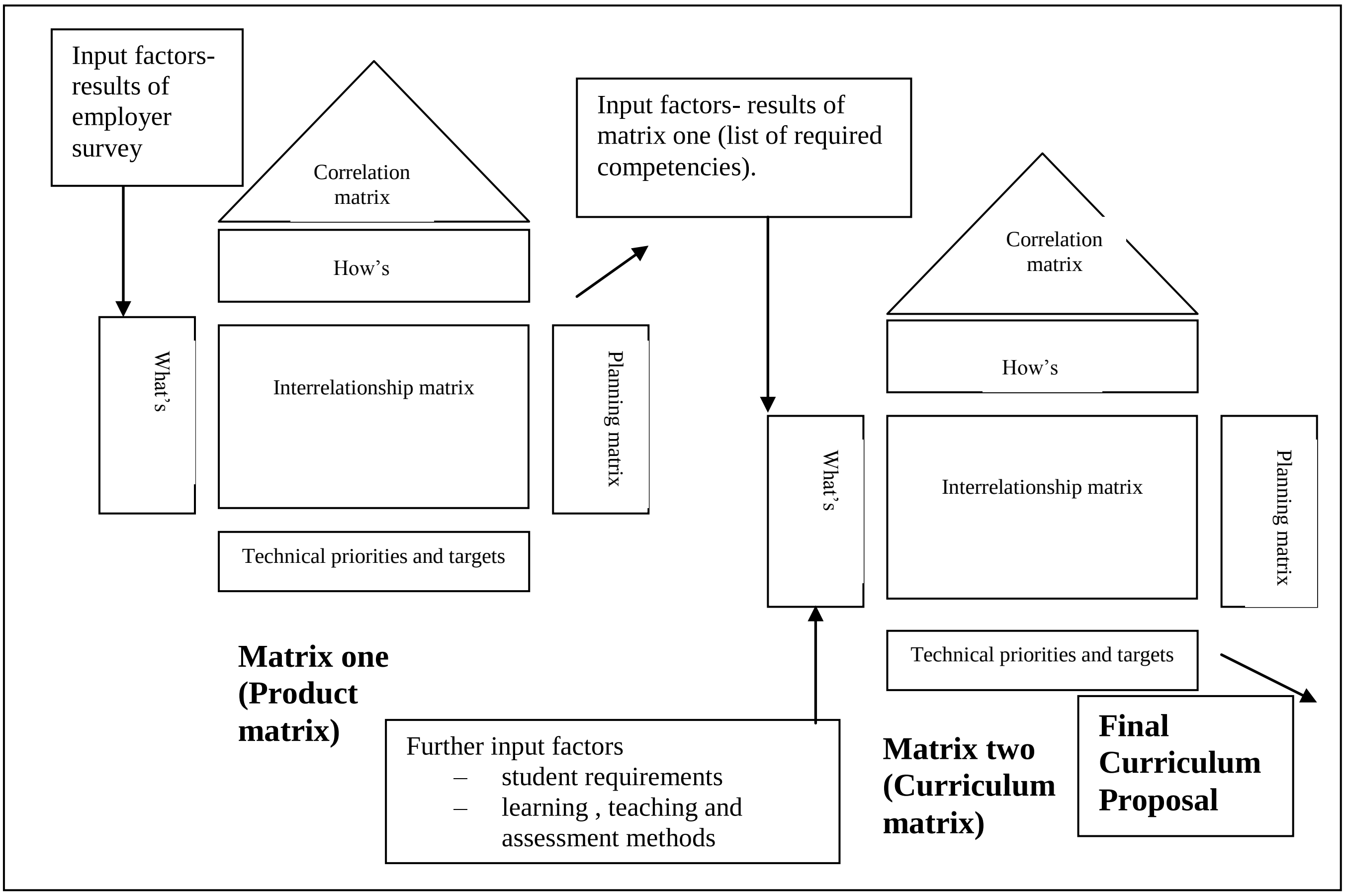

Figure 8.1 Use of a two-phase QFD model.

8.2 QFD - generation of the product matrices.

Customer requirements (What).

The initial task in the QFD analysis was to identify the customers for the product or service under consideration. The nature and extent of the customer base depends on the product or service being provided but in relation to this thesis the primary customer base was taken to be those engineering companies having participated in the employer survey (see chapter 6). The service under investigation being considered to be the educational requirements of those organisations (in relation to Modern Apprentices and other 16-18 year old employees). A secondary group of customers was identified as being the students / Modern Apprentices actually undertaking this education. Using the results of the employer questionnaires an average score of importance was identified for each customer requirement (scores were awarded between 1 and 4 - with a higher number indicating greater importance to the customer requirement).

Technical requirements (How).

This is a structured set of specific, relevant and measurable product or service characteristics. Requirements were prioritised based on the importance to the customer (although it is often desirable to adjust these priorities by considering factors such as internal requirements or strategic planning). In relation to this thesis the technical requirements were considered to be the appropriate teaching module suited to satisfying the customer requirements. Specially, each customer requirement was considered in relation to a range of curriculum subjects (technical requirements) typically undertaken by existing engineering students across the range of awards.

The Planning Matrix.

This section is typically used to illustrate customer perceptions, benchmarking data or the relative importance of each characteristic under investigation. In relation this thesis the planning matrix was used to assess the existing coverage of customer requirements and subsequently to compare the effectiveness of current educational provision.

The Interrelationship Matrix.

This section illustrates the perceived inter-relationship between the technical and customer requirements. In relation to this thesis it allowed for consideration of the relationship between customer requirements (the skills profile) and the teaching module. Coverage of each customer requirement was considered as being either, strong (9 points), medium (4 points) or weak (1point). Cross-referencing the curriculum subjects in this manner allowed for an understanding of the level of coverage (customer satisfaction) currently being provided, as well as the relative importance of each subject area.

The Correlation Matrix.

This section was used to identify where technical requirements support or impede each other in the design of the product or service. These trade-offs, which are located in the roof of the House of Quality therefore indicate the synergistic or detrimental effects of changes that could possibly be made. This area of the House of Quality was therefore used to identify critical compromises in the design where an improvement in one area may possibly be offset with deterioration in performance in another area. In relation to this thesis the technical correlation matrix was used to investigate the correlation between taught modules and the requirements of the customers. Finally, the correlation between taught modules (in satisfying customer requirements) is identified with either a strong correlation or a medium correlation between modules being identified.

Technical Priorities.

The technical priorities matrix is normally used to record the priority of each technical requirement and the degree of difficulty involved in developing each requirement. Within this thesis it was used to assess the importance (level of coverage) of the modules traditionally taught in relation to the customer requirements. The absolute importance of each curriculum subject was calculated by summing the product of each weighted customer requirement and the correlated level of coverage. The relative importance was calculated as a simple percentage for each curriculum subject area

The results of this investigation are displayed as follows.

Figure 8.2 - Product matrix for companies considered to be operating in the top left hand corner of the Puttick grid (high product complexity in markets of high uncertainty).

Figure 8.3 - Product matrix for companies considered to be operating in the bottom left hand corner of the Puttick grid (high product complexity in markets of low uncertainty).

Figure 8.4 - Product matrix for companies considered to be operating in the bottom right hand corner of the Puttick grid (low product complexity in markets of low uncertainty).

	Business management	CAD	CAM	CNC	Electronics	Electrical Principles	Electrical Installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Instrumentation and control	Materials	Mathematics	Mechanical science	Mech laboratories	PLCs	Pneumatics and hydraulics	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements
Business management								😐		☺	☺	☺									☺	☺	😐			😐		☺
CAD			☺	☺							😐			😐		😐					☺							
CAM		☺		☺				☺	☺					😐														😐
CNC		☺	☺					☺	☺					😐												😐		
Electronics						☺					😐	😐	☺		☺			☺	😐		😐			☺			☺	
Electrical principles					☺		☺				😐	😐	☺		☺						😐							
Electrical installation						☺																						
Engineering design	😐		☺	☺					☺		☺	☺		😐	😐					😐	☺	☺				☺		
Engineering drawing			☺	☺				☺													☺					😐		
Environmental management	☺													😐						😐			😐					☺
Group activities	☺	😐			😐	😐		☺				☺				😐	😐				☺						☺	☺
Key Skills	☺				😐	😐		☺			☺				☺	😐	😐				☺					☺	☺	☺
Instrumentation and control					😐	☺									☺			☺						☺				
Materials		😐	😐	😐				😐		😐						😐				☺	☺				☺		☺	
Mathematics					☺	☺		😐				☺	☺			☺		☺			☺		😐	😐				
Mechanical science		😐									😐	😐		😐	☺		☺				☺					😐		
Mechanical laboratories											😐	😐				☺						☺				😐		
PLCs					☺								☺		☺				☺					☺		☺		
Pneumatics and hydraulics					😐													☺									☺	
Primary/ secondary processing								😐		😐				☺							☺							☺
Project	☺	☺			😐	😐		☺	☺		☺	☺		☺	☺	☺				☺		☺	☺			☺		
Project management	☺							☺									☺				☺					☺		
Quality management	😐									😐					😐						☺							
Software design					😐								☺		😐			☺								☺		
Welding														☺														
Working on computers	😐			😐				☺	😐			☺				😐	😐	☺			☺	☺		☺			☺	☺
Workshop activities					😐							☺		☺					☺							☺		
Work placements	☺		😐							☺	☺	☺								☺						☺		

☺	Strong Positive
😐	Medium Positive

Customer requirements	Curriculum design requirments	Customer importance	Business management	CAD	CAM	CNC	Electronics	Electrical Principles	Electrical Installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Instrumentation and control	Materials	Mathematics	Mechanical science	Mech laboratories	PLCs	Pneumatics and hydraulics	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements	Coverage %
Technical requirements	Product development	3.7	□	●	●	▲	▲	▲		●	▲	▲	●			□		▲				▲	▲	▲	□	●		▲			5.2
	Advanced CAD/CAM	2.0		●	●	●				●	▲					□															1.3
	Practical Craft Skills	3.7		□	□	▲	▲	▲	●		□				□			▲	□		▲						●		●		3.1
	Manufacturing technology	3.3		▲	▲	▲				▲	▲	▲			□	●				▲	▲	●	▲				▲		▲	●	3.8
	Material flow	3.0	□			□						▲			□	□				▲	▲	▲									1.0
	Cleaner production	3.0	□	□	▲		□			●		●	□			▲						▲	□		□						1.7
	Sustainable materials	3.7	□							●	□	●	□			●						□	□	□	□						2.0
	Project management	3.0	●							●			●										●	●				▲			2.4
	End of life management	3.3	□	●			□			●		●	□			▲		□					□								1.9
	Logistics and supply management	3.3	▲	□	●	▲				▲		●	□			□						▲	□								2.0
	Quality management	3.7	□							▲	□	●				▲	□					▲			●						2.0
Professional and Business	Business awareness	2.7	●							●		●	▲										▲	▲	▲					●	2.2
	Commerce and profit focus	3.7	●	▲						●		▲	▲										▲	▲	▲					□	2.5
	Customer focus	3.3	●	▲						●		▲	▲										▲	▲	●					●	3.0
	Business development	3.3	●							●		▲	▲										▲	▲	●						2.3
	Persuasiveness	2.3											▲	▲									▲	▲							0.6
	Drive and confidence	3.7											●	▲									●	●							1.8
	Presentational skills	3.0	▲							▲	▲		●	●					▲				●	●				●			2.9
Information handling	Numeracy	4.0	□			□	▲	▲		▲				●	□		●	▲	▲	▲			▲	▲	▲	▲	□		□		4.0
	Ability to exploit IT	3.7	▲	▲	▲	▲				▲	▲			●			▲		▲	▲			▲	●	▲	●		●			4.7
	Higher mathematical ability	3.3					●	●							●		●	●	▲							▲					2.8
	Problem solving	4.0	□	▲		▲	●	●	●	●	▲		●	●	●		●	●	●	●	▲		●	●	●	▲	●	▲	●		10.8
	Innovative thinking	4.0	▲	▲		▲			▲	●			●	●	▲				▲	▲	▲		●	●		●	▲		▲		6.0
Generic skills	Leadership	4											▲	▲									□	□							0.6
	Team working	4								▲			●						●				●	●			□		□	●	3.1
	Creativity	3		▲					▲	●	▲		●	●			▲		▲	▲	▲		●	●		●	▲		▲		4.3
	Communication skills	3.5	□	▲			▲	▲		▲	●		●	●				▲	▲	▲			●	●				●		●	5.2
	Project management	3.5	●	▲			▲	▲		●			●					▲	●				●	●							3.9
	Multicultural skills	3											□	□									□	□						□	0.2
	Time management	4	□	□	□	□	□	□	▲	▲	▲		●	▲	□	□	□	□	▲	□	□	□	●	●	□	□	●		●	□	5.8
	Integrity	4											●	□					●				●	●			▲		▲		2.9
	Building relationships	4								▲			●	□					●				●	●	▲		▲		▲	●	4.0
	Absolute importance		267	223	129	132	150	143	113	550	146	258	520	294	100	119	136	147	293	138	88	104	534	529	256	179	187	135	187	194	
	Relative importnace (%)		4.3	3.6	2.1	2.1	2.4	2.3	1.8	8.8	2.3	4.1	8.3	4.7	1.6	1.9	2.2	2.3	4.7	2.2	1.4	1.7	8.5	8.5	4.1	2.9	3.0	2.2	3.0	3.1	

●	Strong	9
▲	Medium	4
□	Weak	1

Figure 8.2 Product matrix for companies (high product complexity in markets of high uncertainty).

Curriculum design requirements	Business management	CAD	CAM	CNC	Electronics	Electrical Principles	Electrical Installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Instrumentation and control	Materials	Mathematics	Mechanical science	Mech laboratories	PLCs	Pneumatics and hydraulics	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements
Business management								😐		☺	☺	☺									☺	☺	😐			😐		☺
CAD			☺	☺							😐			😐		😐					☺							
CAM		☺		☺				☺	☺					😐														😐
CNC		☺	☺					☺	☺					😐												😐		
Electronics						☺					😐	😐	☺		☺			☺	😐		😐			😐			😐	
Electrical principles					☺		☺				😐	😐	☺		☺						😐							
Electrical installation						☺																						
Engineering design	😐		☺	☺					☺		☺	☺		😐	😐					😐	☺	☺				☺		
Engineering drawing			☺	☺				☺													☺					😐		
Environmental management	☺													😐						😐			😐					☺
Group activities	☺	😐			😐	😐		☺				☺				😐	😐				☺						☺	☺
Key Skills	☺				😐	😐		☺			☺				☺	😐	😐				☺					☺	☺	☺
Instrumentation and control					😐	☺									☺			☺						☺				
Materials		😐	😐	😐				😐		😐						😐				☺	☺				☺		☺	
Mathematics					☺	☺		😐				☺	☺			☺		☺			☺		😐	😐				
Mechanical science		😐									😐	😐		😐	☺		☺				☺					😐		
Mechanical laboratories											😐	😐				☺						☺				😐		
PLCs					☺								☺		☺				☺					☺		☺		
Pneumatics and hydraulics					😐													☺									☺	
Primary/ secondary processing								😐		😐				☺							☺							☺
Project	☺	☺			😐	😐		☺	☺		☺	☺		☺	☺	☺				☺		☺	☺			☺		
Project management	☺							☺									☺				☺					☺		
Quality management	😐									😐					😐						☺							
Software design					😐								☺		😐			☺								☺		
Welding														☺														
Working on computers	😐			😐				☺	😐			☺				😐	😐	☺			☺	☺		☺			☺	☺
Workshop activities					😐							☺		☺					☺							☺		
Work placements	☺		😐							☺	☺	☺								☺						☺		

☺	Strong Positive
😐	Medium Positive

Customer requirements		Customer importance	Business management	CAD	CAM	CNC	Electronics	Electrical Principles	Electrical Installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Instrumentation and control	Materials	Mathematics	Mechanical science	Mech laboratories	PLCs	Pneumatics and hydraulics	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements	Coverage %
Technical requirements	Product development	3.3	□	●	●	▲	▲	▲		●	▲	▲	●			□		▲				▲	▲	▲	□	●		▲			5.3
	Advanced CAD/CAM	2.0		●	●	●				●	▲					□															1.5
	Practical Craft Skills	3.3		□	□	▲	▲	▲	●		□				□			▲	□		▲						●		●		3.1
	Manufacturing technology	3.3		▲	▲	▲				▲	▲	▲			□	●				▲	▲	●	▲				▲		▲	●	4.3
	Material flow	3.3	□			□						▲			□	□				▲	▲	▲									1.2
	Cleaner production	3.7	□	□	▲		□			●		●	□			▲						▲	□		□						2.4
	Sustainable materials	3.0	□							●	□	●	□			●						□	□	□	□						1.8
	Project management	3.3	●							●			●										●	●				▲			2.9
	End of life management	2.3	□	●			□			●		●	□			▲		□					□								1.5
	Logistics and supply management	4.0	▲	□	●	▲				▲		●	□			□						▲	□								2.7
	Quality management	3.7	□							▲	□	●				▲	□					▲			●						2.2
Professional and Business	Business awareness	3.7	●							●		●	▲										▲	▲	▲					●	3.4
	Commerce and profit focus	3.7	●	▲						●		▲	▲										▲	▲	▲					□	2.8
	Customer focus	3.3	●	▲						●		▲	▲										▲	▲	●					●	3.3
	Business development	3.0	●							●		▲	▲										▲	▲	●						2.3
	Persuasiveness	3.0											▲	▲									▲	▲							0.9
	Drive and confidence	3.7											●	▲									●	●							2.0
	Presentational skills	3.0	▲							▲	▲		●	●					▲				●	●				●			3.3
Information handling	Numeracy	3.3	□			□	▲	▲		▲				●	□		●	▲	▲	▲			▲	▲	▲	▲	□		□		3.8
	Ability to exploit IT	2.0	▲	▲	▲	▲				▲	▲			●			▲		▲	▲			▲	●	▲	●		●			2.9
	Higher mathematical ability	2.7					●	●							●		●	●	▲							▲					2.5
	Problem solving	3.0	□	▲		▲	●	●	●	●	▲		●	●	●		●	●	●	●	▲		●	●	●	▲	●	▲	●		9.1
	Innovative thinking	3.3	▲	▲		▲			▲	●			●	●	▲				▲	▲	▲		●	●		●	▲		▲		5.6
Generic skills	Leadership	3											▲	▲									□	□							0.5
	Team working	3.7								▲			●						●				●	●			□		□	●	3.4
	Creativity	3.7		▲					▲	●	▲		●	●			▲		▲	▲	▲		●	●		●	▲		▲		6.0
	Communication skills	3.3	□	▲			▲	▲		▲	●		●	●				▲	▲	▲			●	●				●		●	5.5
	Project management	3	●	▲			▲	▲		●			●					▲	●				●	●							3.8
	Multicultural skills	2											□	□									□	□						□	0.2
	Time management	3	□	□	□	□	□	□	▲	▲	▲		●	▲	□	□	□	□	▲	□	□	□	●	●	□	□	●		●	□	4.4
	Integrity	3											●	□					●				●	●			▲		▲		2.4
	Building relationships	2.7								▲			●	□					●				●	●	▲		▲		▲	●	3.0
	Absolute importance		257	197	126	112	125	119	97	517	137	263	455	253	81	111	110	124	167	119	83	127	480	477	192	150	155	115	157	195	
	Relative importnace (%)		4.8	3.6	2.3	3.0	1.3	2.2	1.8	9.7	2.5	4.8	8.5	4.2	1.5	2.0	2.1	2.2	3.0	2.2	1.5	1.7	8.7	8.7	3.6	2.8	2.9	2.1	2.9	3.4	

●	Strong	9
▲	Medium	4
□	Weak	1

Figure 8.3 Product matrix for companies (high product complexity in markets of low uncertainty).

	Business management	CAD	CAM	CNC	Electronics	Electrical Principles	Electrical Installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Instrumentation and control	Materials	Mathematics	Mechanical science	Mech laboratories	PLCs	Pneumatics and hydraulics	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements
Business management								☺		☺	☺	☺									☺	☺	☺			☺		☺
CAD			☺	☺							☺			☺		☺					☺							
CAM		☺		☺				☺	☺					☺														☺
CNC		☺	☺					☺	☺					☺												☺		
Electronics						☺					☺	☺	☺		☺			☺	☺		☺			☺			☺	
Electrical principles					☺		☺				☺	☺	☺		☺						☺							
Electrical installation						☺																						
Engineering design	☺		☺	☺					☺		☺	☺		☺	☺					☺	☺	☺				☺		
Engineering drawing			☺	☺				☺													☺					☺		
Environmental management	☺													☺						☺			☺					☺
Group activities	☺	☺			☺	☺		☺				☺				☺	☺				☺						☺	☺
Key Skills	☺				☺	☺		☺			☺				☺	☺	☺				☺					☺	☺	☺
Instrumentation and control					☺	☺									☺			☺						☺				
Materials		☺	☺	☺				☺		☺						☺				☺	☺				☺		☺	
Mathematics					☺	☺		☺				☺	☺			☺		☺			☺		☺	☺				
Mechanical science		☺									☺	☺		☺	☺		☺				☺					☺		
Mechanical laboratories											☺	☺				☺						☺				☺		
PLCs					☺								☺		☺				☺					☺		☺		
Pneumatics and hydraulics					☺													☺									☺	
Primary/ secondary processing								☺		☺				☺							☺							☺
Project	☺	☺			☺	☺		☺	☺		☺	☺		☺	☺	☺				☺		☺	☺			☺		
Project management	☺							☺									☺				☺					☺		
Quality management	☺									☺					☺						☺							
Software design					☺								☺		☺			☺								☺		
Welding														☺														
Working on computers	☺			☺				☺	☺			☺				☺	☺	☺			☺	☺		☺			☺	☺
Workshop activities					☺							☺		☺					☺							☺		
Work placements	☺		☺							☺	☺	☺								☺						☺		

Curriculum design requirments

Customer requirements		Customer importance	Business management	CAD	CAM	CNC	Electronics	Electrical Principles	Electrical Installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Instrumentation and control	Materials	Mathematics	Mechanical science	Mech laboratories	PLCs	Pneumatics and hydraulics	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements	Coverage %
Technical requirements	Product development	3.0	□	●	●	▲	▲	▲		●	▲	▲	●			□		▲				▲	▲	▲	□	●		▲			4.3
	Advanced CAD/CAM	1.7		●	●	●				●	▲					□															1.1
	Practical Craft Skills	3.3		□	□	▲	▲	▲	●		□				□			▲	□		▲						●		●		2.8
	Manufacturing technology	3.3		▲	▲	▲				▲	▲	▲			□	●				▲	▲	●	▲				▲		▲	●	3.9
	Material flow	4.0	□			□						▲			□	□				▲	▲	▲									1.3
	Cleaner production	4.0	□	□	▲		□			●		●	□			▲						▲	□		□						2.3
	Sustainable materials	4.0	□							●	□	●	□			●						□	□	□	□						2.2
	Project management	4.0	●							●			●										●	●				▲			3.2
	End of life management	4.0	□	●			□			●		●	□			▲		□					□								2.3
	Logistics and supply management	3.7	▲	□	●	▲				▲		●	□			□						▲	□								2.3
	Quality management	4.0	□							▲	□	●				▲	□					▲			●						2.2
Professional and Business	Business awareness	3.3	●							●		●	▲										▲	▲	▲					●	2.8
	Commerce and profit focus	4.0	●	▲						●		▲	▲										▲	▲	▲					□	2.8
	Customer focus	4.0	●	▲						●		▲	▲										▲	▲	●					●	3.7
	Business development	3.3	●							●		▲	▲										▲	▲	●						2.3
	Persuasiveness	3.3											▲	▲									▲	▲							0.9
	Drive and confidence	3.3											●	▲									●	●							1.7
	Presentational skills	3.3	▲							▲	▲		●	●					▲				●	●				●			3.3
Information handling	Numeracy	3.3	□			□	▲	▲		▲				●	□		●	▲	▲	▲			▲	▲	▲	▲	□		□		3.4
	Ability to exploit IT	3.7	▲	▲	▲	▲				▲	▲			●			▲		▲	▲			▲	●	▲	●		●			4.8
	Higher mathematical ability	3.0					●	●							●		●	●	▲							▲					2.6
	Problem solving	4.0	□	▲		▲	●	●	●	●	▲		●	●	●		●	●	●	●	▲		●	●	●	▲	●	▲	●		11.0
	Innovative thinking	4.0	▲	▲		▲			▲	●			●	●					▲	▲	▲		●	●		●	▲		▲		5.9
Generic skills	Leadership	3.7											▲	▲									□	□							0.6
	Team working	4.0								▲			●						●				●	●			□		□	●	3.3
	Creativity	3.0		▲					▲	●	▲		●	●			▲		▲	▲	▲		●	●		●	▲		▲		4.4
	Communication skills	3.3	□	▲			▲	▲		▲	●		●	●				▲	▲	▲			●	●				●		●	5.0
	Project management	3.0	●	▲			▲	▲		●			●					▲	●				●	●							3.4
	Multicultural skills	2.3											□	□									□	□						□	0.2
	Time management	3.3	□	□	□	□	□	□	▲	▲	▲		●	▲	□	□	□	□	▲	□	□	□	●	●	□	□	●		●	□	4.4
	Integrity	3.3											●	□					●				●	●			▲		▲		2.4
	Building relationships	3.0								▲			●	□					●				●	●	▲		▲		▲	●	3.0
	Absolute importance		273	215	96	110	138	130	107	570	142	284	488	284	78	129	127	134	279	138	81	112	520	538	221	168	165	133	165	130	
	Relative importnace (%)		4.6	3.6	1.6	1.8	2.3	2.2	1.8	9.6	2.4	4.8	8.2	4.8	1.3	2.2	2.1	2.3	4.7	2.3	1.4	1.9	8.7	9.0	3.7	2.8	2.8	2.2	2.8	2.2	

☺	Strong Positive
😐	Medium Positive

●	Strong	9
▲	Medium	4
□	Weak	1

Figure 8.4 Product matrix for companies (low product complexity in markets of low uncertainty).

8.2.1 Discussion of results - product matrices.

Summing the product of each weighted customer requirement and the correlated level of coverage across all the curriculum subjects it was possible to assess the satisfaction level for each customer requirement against curriculum subjects. This was particularly important in allowing for the determination of a profile of the importance of customer requirements against the levels of coverage provided by existing curriculum subject areas. See figure 8.5 for those companies operating within a market of high business uncertainty and high product complexity, figure 8.6 for those companies operating within a market of low business uncertainty and high product complexity and figure 8.7 for those companies operating within a market of low business uncertainty and low product complexity.

In utilising these results it was not possible to accurately relate the level of coverage to customer importance although it was considered reasonable to expect that a general correlation between increasing customer importance and increasing level of coverage would be present. When considering each competency area in turn this general level of correlation was subsequently examined. Firstly, in the case of professional and business skills serious discrepancies between the levels of coverage and stated customer importance were noted. Particular imbalances were noted for developing drive and confidence, persuasiveness, and to a lesser extent with the development of commercial and profit focus and business development skills. Secondly, when considering technical skills it was noted that despite a broad correlation in many areas the development of competencies centred on materials usage and control was too low. This was particularly evident with the low level of coverage in the areas of materials flow, clearer production, sustainable manufacture, end-of-life management and logistics and supply management. Conversely it was noted that product development skills (assumed to involve teaching and learning of design methodologies, drawing skills etc) had too high a level of coverage. The third competency area considered was that of information handling. Despite broad correlation of coverage to customer requirement levels in areas such as numeracy, exploitation of IT and the development of higher mathematical ability it was noted that the development of problem-solving abilities and innovative thinking had very high levels of coverage. This is consistent with the traditional approach to teaching of many engineering subjects were emphasis is placed on the numeric solution of mechanical and design problems. Finally, in considering the development of generic skills significant results included identifying that the development of leadership and multi-cultural skills suffered from too low a level of coverage whilst that of developing creativity was too high. Specifically in relation to each individual quadrant of the Puttick gird these general profiles were also investigated.

Firstly, in considering those companies operating within a market considered to be characterised by high business uncertainty and high product complexity it was noted that these organisations rated information handling skills as the most important skill area with problem solving, innovative thinking and numeracy all being highlighted. All these areas currently enjoy very high levels of coverage in the existing curricula. In terms of generic skills development (classified as the second most important area within this quadrant) there was noted to be a more even distribution of coverage against the customer's requirements. Significant shortfalls against customer expectation were however observed in terms of developing leadership skills and multicultural skills. In summarizing the results for this quadrant of the Puttick grid it is concluded that these organisations are generally being well served with most of the competency areas they expressed as being important being adequately covered and developed in existing courses of educational study. Areas where deficiencies were noted include the development of some generic skills such as leadership and to a lesser extent the development of technical skills relating to materials usage and control.

Secondly, when considering those companies operating within a market characterised to have low business uncertainty and high product complexity it was noted that organisations rated professional skills development as the most important competency area with business awareness, commercial and profit focus, customer focus and drive and confidence all being highlighted. Overall, it is considered that these skills are not currently very well serviced within the existing curriculum with significant deficiencies in coverage noted in the areas of business development, commercial and profit focus and the development of drive and confidence. In terms of technical skills development (classified as the second most important competency area) it was noted that significant shortfalls were again present in areas related to materials usage and control such as logistics, material flow, cleaner production and end-of- life management. In considering the development of generic skills and information handling skills the shortfall is less dramatic. Summarizing the results for this quadrant of the Puttick grid it is concluded that generally these organisations are being poorly served by existing courses of educational study.

Finally, in considering those companies operating within a market characterised to have low business uncertainty and low product complexity it was noted that these organisations rated most highly the need for technical and professional skills followed closely by generic and the information handling skills. Therefore similar deficiencies to those discussed for companies operating within a market characterised to have low business uncertainty and high product complexity can be identified (see above) but since this is a more diverse picture than the two quadrants previously considered the significance of each area of shortfall will be reduced.

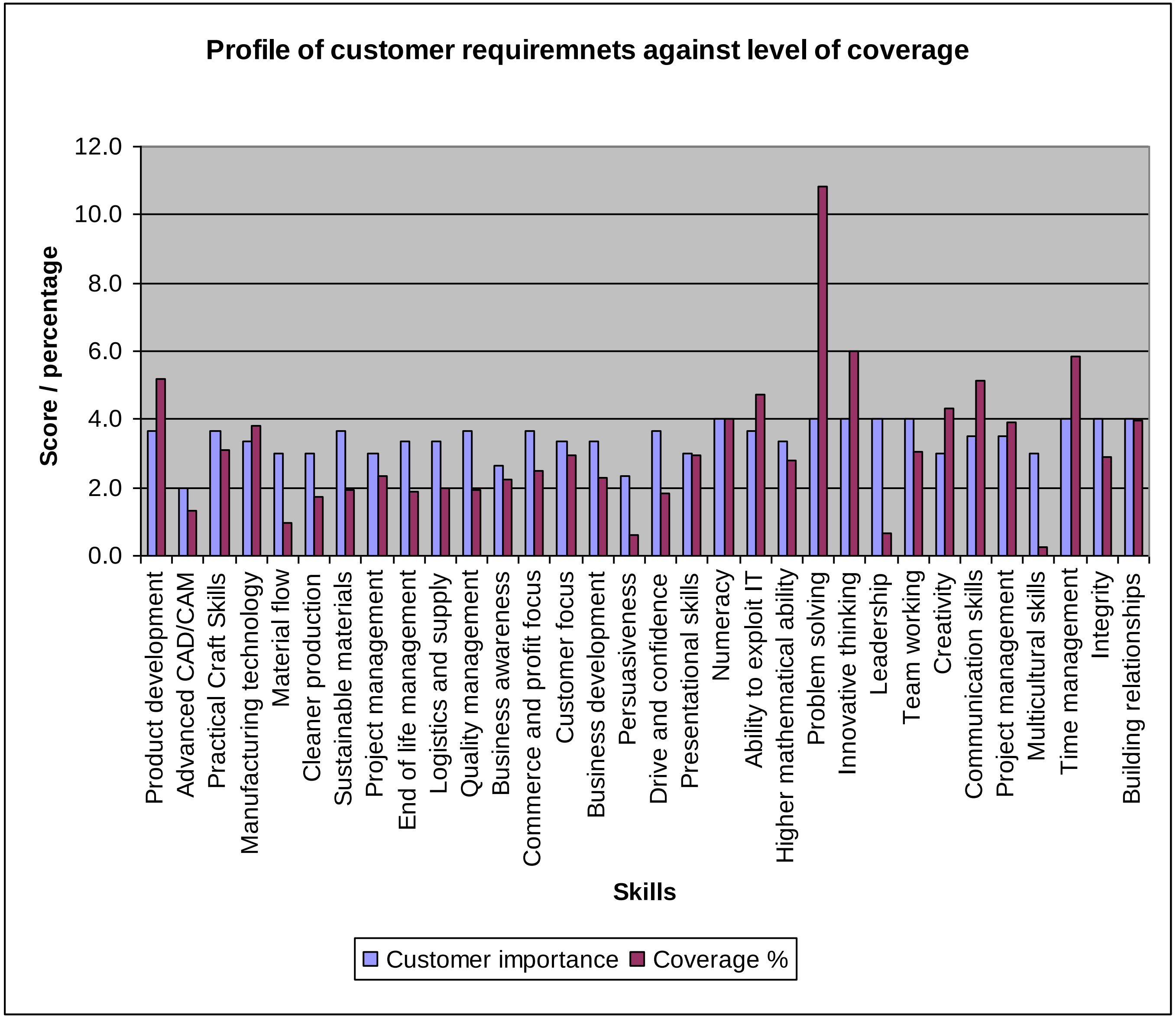

Figure 8.5 Profile of customer requirements against level of coverage (high product complexity in markets of high uncertainty).

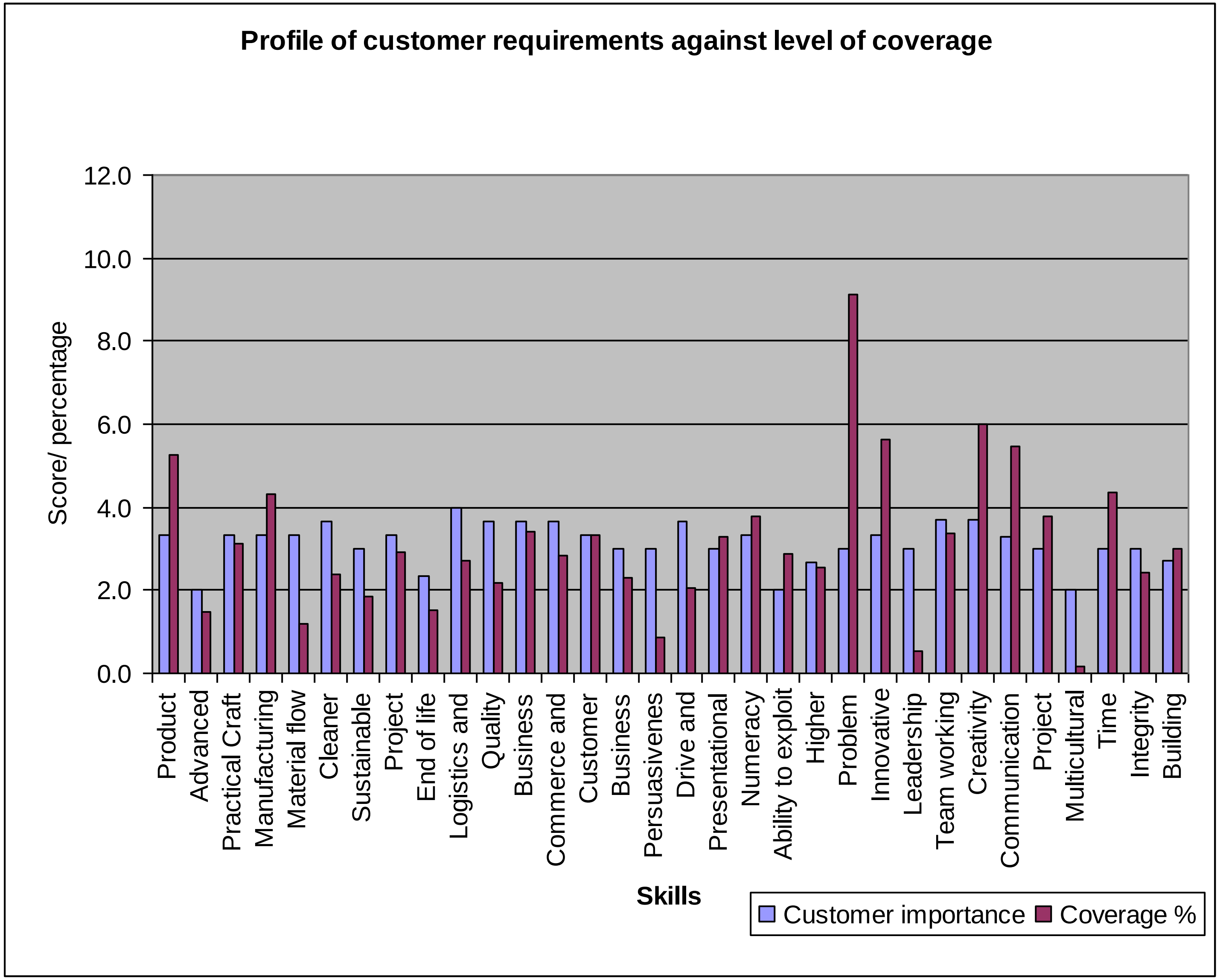

Figure 8.6 Profile of customer requirements against level of coverage (high product complexity in markets of low uncertainty).

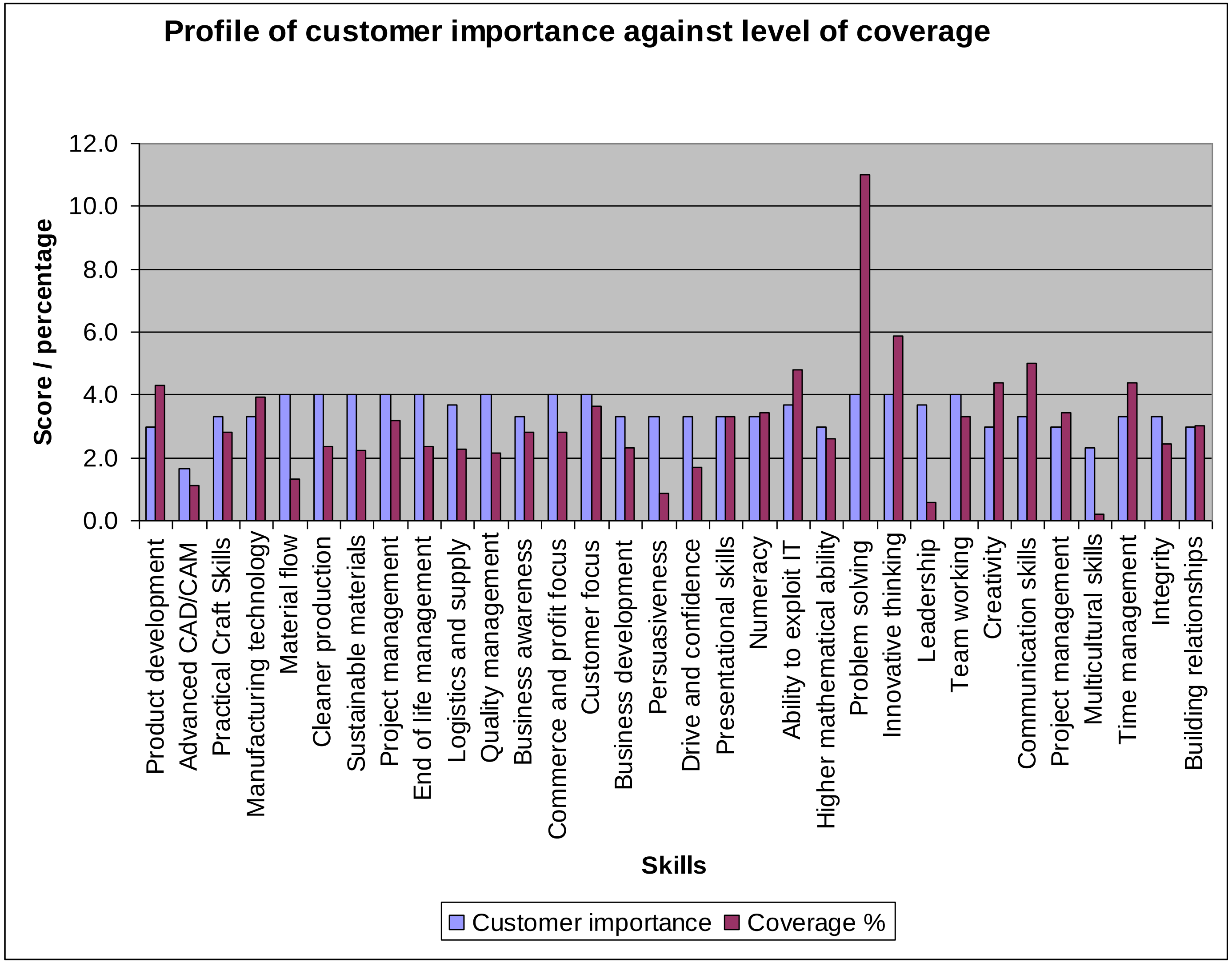

Figure 8.7 Profile of customer requirements against level of coverage (low product complexity in markets of low uncertainty).

8.3 QFD - generation of the curriculum matrices.

The output from each respective product matrix was the identification of the curriculum teaching modules best reflecting and developing the competencies required by the employers. It was decided that only the salient customer requirements would be included in the curriculum matrix and therefore any customer requirement graded at 3 or below was disregarded. Hence, only those requirements considered to be important or very important were included in the subsequent curriculum matrices. See tables 8(i), 8(ii) and 8(iii) for the customer requirements included for each respective quadrant of the Puttick grid.

Customer requirement	Customer importance
Numeracy	4
Problem solving	4
Innovative thinking	4
Leadership	4
Team working	4
Time management	4
Integrity	4
Building relationships	4
Product development	3.7
Practical craft skills	3.7
Sustainable materials	3.7
Quality management	3.7
Commerce and profit focus	3.7
Drive and confidence	3.7
Ability to exploit IT	3.7
Communication skills	3.5
Project management	3.5
Manufacturing technology	3.3
End of life management	3.3
Logistics and supply management	3.3
Customer focus	3.3
Business development	3.3
Higher mathematical ability	3.3

Table 8(i) List of customer requirements included in the curriculum matrix (high product complexity / high market uncertainty).

Customer requirement	Customer importance
Logistics and supply management	4
Team working	3.7
Creativity	3.7
Cleaner production	3.7
Quality management	3.7
Business awareness	3.7
Commercial and profit focus	3.7
Drive and confidence	3.7
Product development	3.3
Practical craft skills	3.3
Manufacturing technology	3.3
Material flow	3.3
Project management	3.3
Customer focus	3.3
Numeracy	3.3
Innovative thinking	3.3
Communication skills	3.3

Table 8(ii) List of customer requirements included in the curriculum matrix (high product complexity / low market uncertainty).

Customer requirement	Customer importance
Materials flow	4
Cleaner production	4
Sustainable materials	4
Project management	4
End of life management	4
Quality management	4
Commercial and profit focus	4
Customer focus	4
Problem solving	4
Innovative thinking	4
Team working	4
Logistics and supply management	3.7
Ability to exploit IT	3.7
Leadership	3.7
Practical craft skills	3.3
Manufacturing technology	3.3
Business awareness	3.3
Business development	3.3
Persuasiveness	3.3
Drive and confidence	3.3
Presentational skills	3.3
Numeracy	3.3
Communications skills	3.3
Time management	3..3
Integrity	3.3

Table 8(iii) List of customer requirements included in the curriculum matrix (low product complexity / low market uncertainty).

Furthermore, those modules with less than 2% coverage (on the relative importance score) were also disregarded and therefore only modules which to a larger extent addressed the customer requirements were subsequently used in the curriculum matrixes. Considering each quadrant in turn the following modules were identified for inclusion within the curriculum matrices.

Companies operating in markets of high product complexity and high uncertainty. The most significant modules (to allow for coverage of the stated customer requirements) were project (8.3%), project management (8.2%), group activities (8.0%), mechanical laboratories, (5.2%) and Key Skills (4.4%). Other important modules highlighted included business management (3.8%), environmental management (3.8%) and CAD (3.9%). It is considered that these modules clearly reflected the stated desire for the development of information handling and generic skills. See table 8(iv) for a full listing of modules included in the curriculum matrix.

Companies operating in markets of high product complexity and low uncertainty. The most significant modules (again to allow for coverage of the stated customer requirements) were engineering design (10.1%), project (8.4%), group activities (8.1%), project management (7.8%) and environmental management (6.1%). Other important modules highlighted included business management (5.3%) work placements (4.8%), key skills (4.1%) and CAD (3.7%). It is considered that the results reflect an increased emphasis on the stated desire for the development of professional and technical skills. See table 8(v) for a full listing of modules included in the curriculum matrix.

Module title	Relative importance (%)
Business management	3.8
CAD	3.9
Electronics	2.8
Electrical Principles	2.8
Electrical Installation	2.0
Engineering design	3.8
Engineering drawing	2.3
Environmental management	3.8
Group activities	8.0
Key skills	4.4
Materials	2.0
Mathematics	2.4
Mechanical science	2.8
Mechanical laboratories	5.2
PLCs	2.2
Project	8.3
Project management	8.2
Quality management	3.9
Software design	2.9
Welding	3.4
Workshop practices	3.4
Work placements	2.9

Table 8(iv)
List of modules included in the curriculum matrix (high product complexity / high market uncertainty).

Module title	Relative importance (%)
Business management	5.3
CAD	3.7
CAM	2.9
CNC	2.3
Engineering design	10.1
Engineering drawing	2.3
Environmental management	6.1
Group activities	8.1
Key skills	4.1
Materials	2.1
Mechanical laboratories	2.7
PLCs	2.4
Pneumatics and hydraulics	2.0
Primary and secondary processes	3.1
Project	8.4
Project management	7.8
Quality management	3.4
Software design	3.2
Welding	2.3
Workshop practices	2.3
Work placements	4.8

Table 8(v)
List of modules included in the curriculum matrix (high product complexity / low market uncertainty).

Companies operating in markets of low product complexity and low uncertainty.

The most significant modules (again to allow for coverage of the stated customer requirements) were engineering design (9.4%), project (8.8%), project management (8.7%), group activities (8.2%), environmental management (5.6%) and business management (5.3%). Other important modules highlighted included key skills (5.2%), quality management (4.1%) and mechanical laboratories (3.8%). See table 8(vi) for a full listing of modules included in the curriculum matrix.

Module title	Relative importance (%)
Business management	5.3
CAD	3.0
Electrical installation	2.0
Engineering design	9.4
Engineering drawing	2.3
Environmental management	5.6
Group activities	8.2
Key skills	5.2
Materials	2.5
Mechanical laboratories	3.8
PLCs	2.4
Primary and secondary processes	2.0
Project	8.8
Project management	8.7
Quality management	4.1
Software design	2.0
Welding	3.0
Workshop practices	2.7
Working on computers	3.0
Work placements	3.6

Table 8(vi)
List of modules included in the curriculum matrix (low product complexity / low market uncertainty).

The next stage in the development of the curriculum matrix was to consider how to ensure complementary learning and assessment methods to the needs of the students and the requirements of the employers would be included and a two-stage approach was used. This was completed by firstly using the findings of the learning theory and curriculum modelling literature review (see chapter 5) and secondly by using the results from the two student surveys (see chapter 7).

In terms of the literature review it was decided initially cross-reference suitable learning and assessment methods to what were considered to be the appropriate taxonomy levels within each domain of learning. Since the curriculum being developed is for the education of 16-18 years olds it was decided that this correlated to the first three levels within each of the taxonomies. Secondly, the results from the student learning styles survey were cross-referenced against suitable learning and assessment methods and this was achieved by weighting the preferred learning styles in the same manner as used to define employer requirements (see chapter 8.2 for details). It was therefore concluded that the most preferred learning style (across the entire population sampled) was to be weighted with a customer requirement of 4 (i.e. the activist style) and the second preferred learning style (i.e. the pragmatist style) weighted with a customer requirement of 3. The two least preferred learning styles (reflector and theorist) were omitted from the curriculum matrix. Finally, the results from the general student survey were used to include the stated preferences of students with regard to learning and assessment methods. Again this was achieved by weighting the preferred learning and assessment methods in the same manner as used to define employer requirements (using a scale from 1 to 4).The fully developed curriculum matrix of each sector the Puttick grid is shown as follows.

Figure 8.8 - Curriculum matrix for companies considered to be operating top left hand corner of the Puttick grid (high product complexity in markets of high uncertainty).

Figure 8.9 – Curriculum matrix for companies considered to be operating bottom left hand corner of the Puttick grid (high product complexity in markets of low uncertainty).

Figure 8.10 - Curriculum matrix for companies considered to be operating bottom right hand corner of the Puttick grid (low product complexity in markets of low uncertainty).

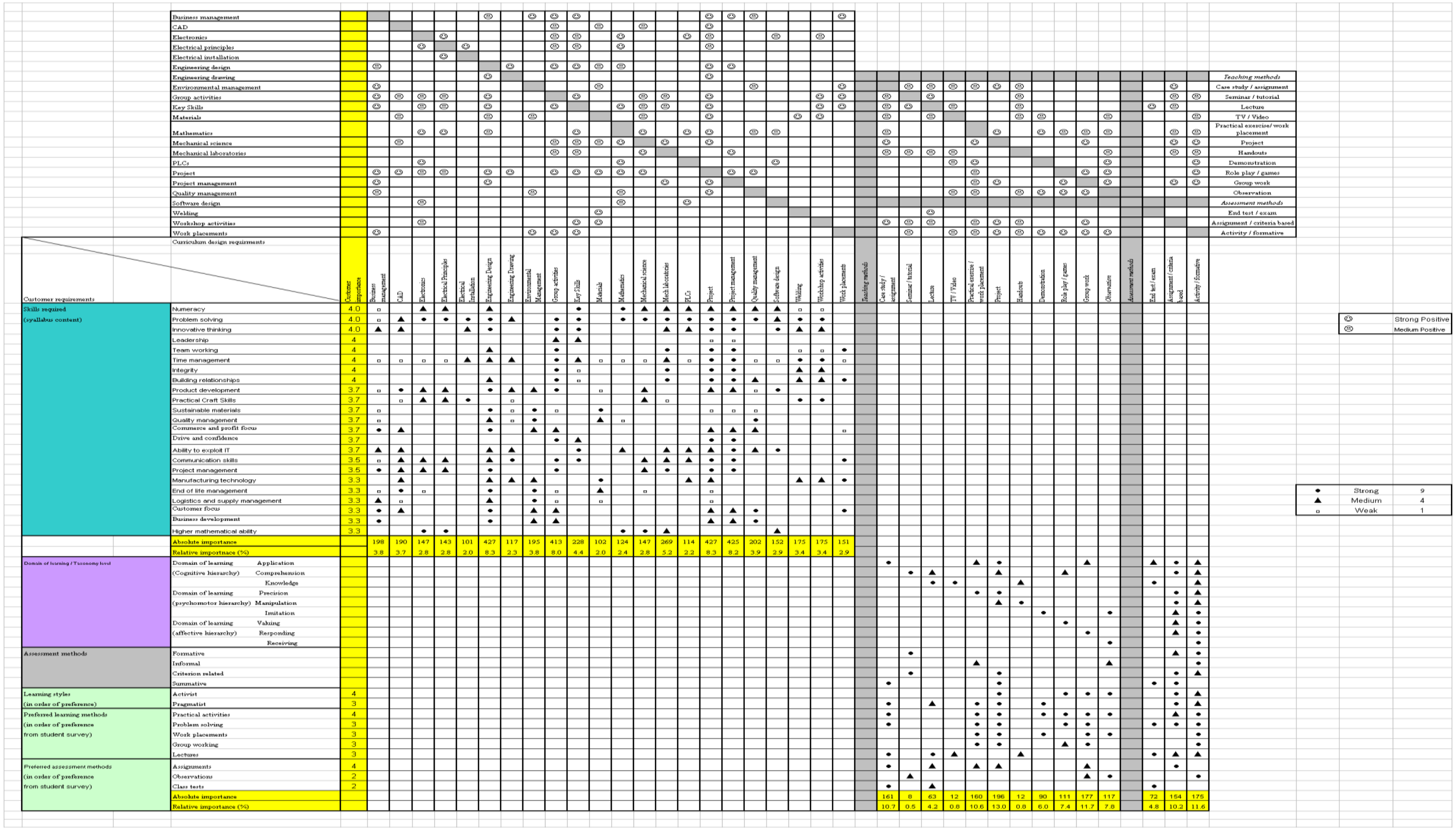

Figure 8.8 Curriculum matrix for companies (high product complexity in markets of high uncertainty).

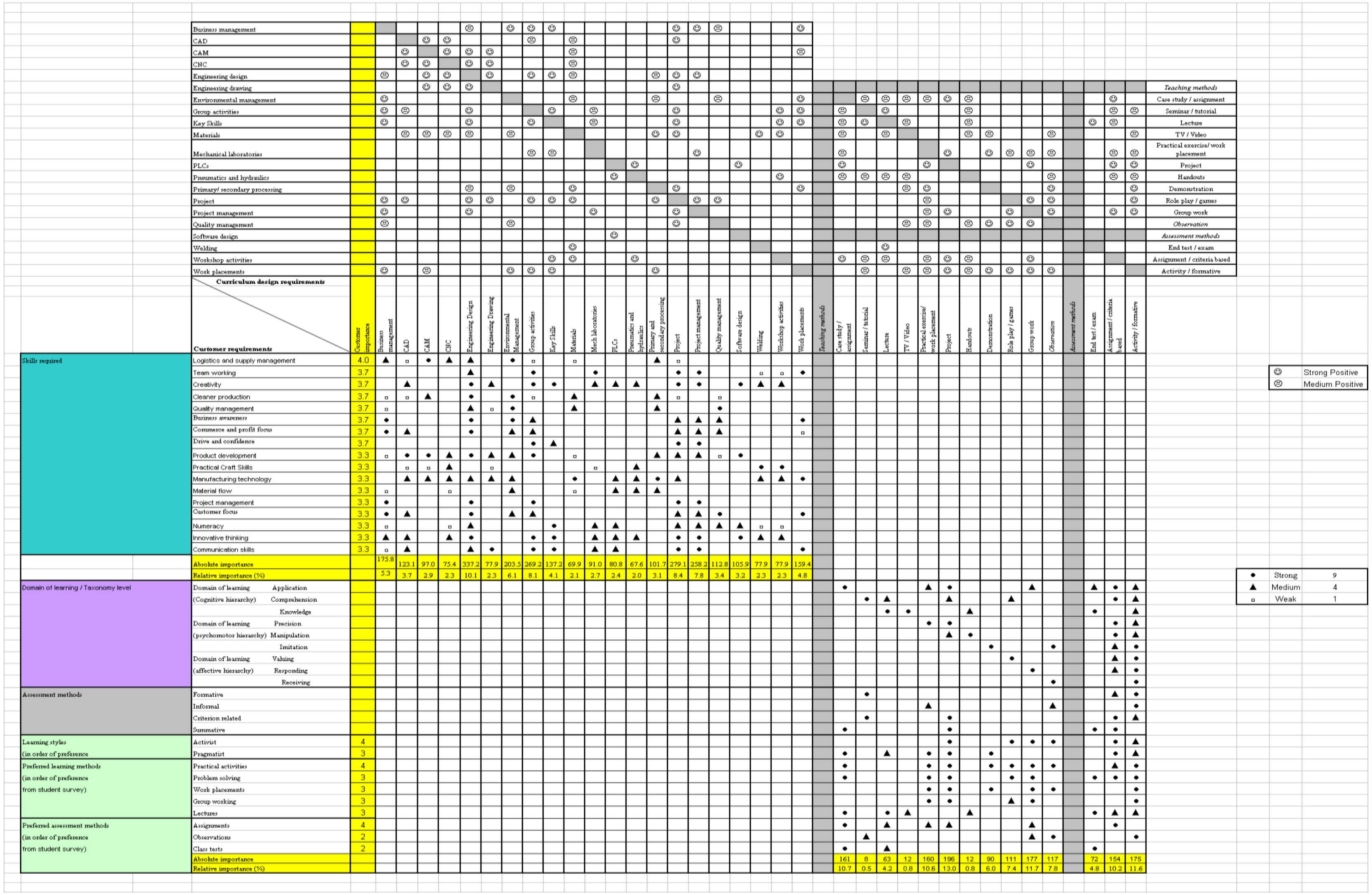

Figure 8.9 Curriculum matrix for companies (high product complexity in markets of low uncertainty).

Curriculum design requirements	Business management	CAD	Electrical installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Materials	Mech laboratories	PLCs	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements
Business management				😐		☺	☺	☺					☺	☺	😐			😐		☺
CAD							😐		😐				☺							
Electrical installation																				
Engineering design	😐				☺		☺	☺	😐			😐	☺	☺				☺		
Engineering drawing				☺									☺					😐		
Environmental management	☺								😐			😐			😐					☺
Group activities	☺	😐		☺				☺		😐			☺						☺	☺
Key Skills	☺			☺			☺			😐			☺					☺	☺	☺
Materials		😐		😐		😐						☺	☺				☺		☺	
Mechanical laboratories							😐	😐						☺				😐		
PLCs																☺		☺		
Primary/ secondary processing				😐		😐			☺				☺							☺
Project	☺	☺		☺	☺		☺	☺	☺			☺		☺	☺			☺		
Project management	☺			☺						☺			☺					☺		
Quality management	😐					😐							☺							
Software design											☺							☺		
Welding									☺											
Working on computers	😐			☺	😐			☺		😐	☺		☺	☺		☺			☺	☺
Workshop activities								☺	☺									☺		
Work placements	☺					☺	☺	☺				☺						☺		

Teaching methods	Case study / assignment	Seminar / tutorial	Lecture	TV / Video	Practical exercise / work placement	Project	Handouts	Demonstration	Role play / games	Group work	Observation	Assessment methods	End test / exam	Assignment / criteria based	Activity / formative
Case study / assignment		😐	😐	😐	😐	☺	😐							☺	
Seminar / tutorial	😐		☺				😐							😐	😐
Lecture	😐	☺		😐			😐						☺	😐	
TV / Video	😐		😐				😐	😐			😐				😐
Practical exercise/ work placement	😐					☺		☺	😐	😐	😐			😐	😐
Project	☺				☺					☺				☺	☺
Handouts	😐	😐	😐	😐							😐			😐	😐
Demonstration				😐	☺						☺				☺
Role play / games					😐					☺	☺				☺
Group work					😐	☺			☺		☺			☺	☺
Observation				😐	😐		😐	☺	☺	☺					
Assessment methods															
End test / exam			☺												
Assignment / criteria based	☺	😐	😐		😐	☺	😐			☺					
Activity / formative		😐		😐	😐	☺	😐	☺	☺	☺	☺				

Customer requirements		Customer importance	Business management	CAD	Electrical installation	Engineering Design	Engineering Drawing	Environmental Management	Group activities	Key Skills	Materials	Mech laboratories	PLCs	Primary and secondary processing	Project	Project management	Quality management	Software design	Welding	Working on computers	Workshop activities	Work placements
Skills required (syllabus content)	Material flow	4.0	○					▲			○		▲	▲								
	Cleaner production	4.0	○	○		●		●	○		▲			▲	○		○					
	Sustainable materials	4.0	○			●	○	●	○		●			○	○	○	○					
	Project management	4.0	●			●			●						●	●				▲		
	End of life management	4.0	○	●		●		●	○		▲				○							
	Quality management	4.0	○			▲	○	●			▲			▲			●					
	Commerce and profit focus	4.0	●	▲		●		▲	▲						▲	▲	▲					○
	Customer focus	4.0	●	▲		●		▲	▲						▲	▲	●					●
	Problem solving	4.0	○	▲	●	●	▲		●	●		●	●		●	●	●	▲	●	▲	●	
	Innovative thinking	4.0	▲	▲	▲	●			●	●		▲	▲		●	●		●	▲		▲	
	Team working	4.0				▲			●			●			●	●			○		○	●
	Logistics and supply management	3.7	▲	○		▲		●	○		○			▲	○							
	Ability to exploit IT	3.7	▲	▲		▲	▲			●		▲	▲		▲	●	▲	●		●		
	Leadership	3.7							▲	▲					○	○						
	Practical Craft Skills	3.3		○	●		○					○							●		●	
	Manufacturing technology	3.3		▲		▲	▲	▲			●		▲	●	▲				▲		▲	●
	Business awareness	3.3	●			●		●	▲						▲	▲	▲					●
	Business development	3.3	●			●		▲	▲						▲	▲	●					
	Persuasiveness	3.3							▲	▲					▲	▲						
	Drive and confidence	3.3							●	▲					●	●						
	Presentational skills	3.3	▲			▲	▲		●	●		▲			●	●				●		
	Numeracy	3.3	○			▲				●		▲	▲		▲	▲	▲	▲	○		○	
	Communication skills	3.3	○	▲		▲	●		●	●		▲	▲		●	●				●		●
	Time management	3.3	○	○	▲	▲	▲		●	▲	○	▲	○	○	●	●	○	○	●		●	○
	Integrity	3.3							●	○		●			●	●			▲		▲	
	Absolute importance		272.7	155.5	101.2	487.6	117.7	287.7	426.1	271	131	194.9	125.7	106.1	456.2	449.8	212.5	101.8	157.7	137.3	157.7	187.3
	Relative importance (%)		5.3	3.0	2.0	9.4	2.3	5.6	8.2	5.2	2.5	3.8	2.4	2.0	8.8	8.7	4.1	2.0	3.0	2.7	3.0	3.6

			Teaching methods	Case study / assignment	Seminar / tutorial	Lecture	TV / Video	Practical exercise / work placement	Project	Handouts	Demonstration	Role play / games	Group work	Observation	Assessment methods	End test / exam	Assignment / criteria based	Activity / formative
Domain of learning / Taxonomy level	Domain of learning (Cognitive hierarchy) Application			●				▲	●				▲			▲	●	▲
	Comprehension				●	▲			▲			▲					●	▲
	Knowledge					●	●			▲						●		▲
	Domain of learning (psychomotor hierarchy) Precision							●	●								●	▲
	Manipulation								▲	●							●	▲
	Imitation										●			●			▲	●
	Domain of learning (affective hierarchy) Valuing											●					▲	●
	Responding												●				▲	●
	Receiving													●				●
Assessment methods	Formative				●												▲	●
	Informal							▲						▲				●
	Criterion related				●				●								●	▲
	Summative			●					●							●	●	
Learning styles (in order of preference)	Activist	4							●			●	●	●			●	▲
	Pragmatist	3		●		▲		●	●		●						●	▲
Preferred learning methods (in order of preference from student survey)	Practical activities	4		●				●	●		●	●	●	●			▲	●
	Problem solving	3		●				●	●			●	●			●	●	●
	Work placements	3						●	●		●		●	●				●
	Group working	3						●	●			▲	●					●
	Lectures	3		●		●	▲			▲						●	▲	▲
Preferred assessment methods (in order of preference from student survey)	Assignments	4		●		▲		▲	▲				▲				●	
	Observations	2			▲								▲	●				●
	Class tests	2		●		▲										●		
	Absolute importance			161	8	63	12	160	196	12	90	111	177	117		72	154	175
	Relative importance (%)			10.7	0.5	4.2	0.8	10.6	13.0	0.8	6.0	7.4	11.7	7.8		4.8	10.2	11.6

☺ Strong Positive
😐 Medium Positive

●	Strong	9
▲	Medium	4
○	Weak	1

Figure 8.10 Curriculum matrix for companies (low product complexity in markets of low uncertainty).

8.3.1 Discussion of results - curriculum matrices.

Despite differing profiles from each curriculum matrix a significant degree of commonality is evident in the results. In particular the project, project management, group activities, environmental management, key skills and business management modules were heavily weighted in the results. Therefore, in terms of the curriculum proposal, it was considered that these modules should form its foundation as they quite clearly demonstrate an ability to develop the range of skills required by employers. However, since it is very difficult to completely satisfy all the competing requirements highlighted in each curriculum matrices, the reminder of the modules selected for inclusion within the curriculum proposal had to be carefully selected in order to balance out the completing demands of each individual sector. To reflect the weighting of each customer requirement the project, project management, group activities, environmental management, key skills and business management activities were double weighted in the curriculum proposal. The preferred learning and assessment methods were also incorporated. It was also possible to determine the preferred learning and assessment methods and the final output of the QFD curriculum matrix is summarised in table 8(vii).

Preferred learning method	Rating	Preferred assessment method	Rating
Project	13	Activity / formative	11.6
Group work	11.7	Assignment / criteria based	10.2
Case study / assignment	10.7	End test exam	4.8
Practical exercise/ work placement	10.6		
Observation	7.8		
Role play / games	7.4		
Demonstration	6.0		
Lecture	4.2		
TV/video	0.8		
Handouts	0.8		
Seminar/ tutorial	0.5		

Table 8(vii) Preferred learning and assessment methods.

It is recognised that the preferred learning and assessment methods are concerned to a large extent with participatory and discovery-lead activities as opposed to more formalised presentational methods. In relation to each domain of learning this is associated in increased development of the higher levels within the respective taxonomies. This is considered to accurately reflect the requirements of students and employers in seeking to develop higher levels of transferable, technical and vocational skills. However in comparing the results against each domain of learning it is apparent that the preferred learning and assessment methods appear to place increased emphasis on the development of cognitive and psychomotor skills rather than the development of affective skills and this probably reflects on the applied nature of engineering as a discipline and the requirements of the students / employers.

To ensure a more balanced development of skills within each domain the practical implementation of the curriculum proposal should seek to increase the use of learning and assessment methods which develop students within the affective domain. Therefore although acknowledging the stated preferences of the students towards particular learning and assessment methods it is necessary to ensure the range of learning and assessment activities proposed provide for adequate coverage of the entire learning cycle and each respective domain of learning. Assuming a broad correlation between the stage of learning and the hierarchal levels within each domain of learning it was therefore possible to construct a teaching and learning schedule to ensure incremental advancement within each of the individual taxonomy whilst ensuring that the teaching and learning methods used are complementary to the requirements of the students and employers.

Taking the salient features of the curriculum profile (as identified in chapter 5.7) and the results of this chapter it was then possible to construct a finalised curriculum proposal (see figure 8.11).

8.4 Summary.

A two-stage approach of using QFD has been utilised and a curriculum profile which reflects the requirements of employers and complementary to the learning needs of the students established.

The first stage of the process (the construction of product matrices) enabled the identification of suitable learning modules. These modules are considered to most adequately allow the development of the competencies required by the employers.

The second stage of the process (the construction of curriculum matrices) considered the delivery of the modules and additional design elements were factored into the final curriculum proposal. In particular, it was possible to incorporate suitable teaching, learning and assessment methods which were complementary to the preferred learning styles of the students and appropriate to the taxonomy levels being studied.

Curriculum Design Stages

Establish curriculum objectives.

Determine learning experiences.

Organisation of learning.

Evaluation of planning.

Characteristic	
Identifying and analysing needs	
Student perspective	Development of skills, personal development and contextualised to real life situations.
Employer perspective	Development of skills as per QFD results and contribution to company success.
Course rationale, aims and objectives	
Student perspective	Employability and personal development.
Employer perspective	Employability skills.
Function of the course	Holistic growth of student.
Learning perspective	Learner-centeredness, APL/ APEL considered relevance to life and work.
Detailing course syllabi	Development against competency profiles
Content	Practical , real life applications, reflective
Context of learning	2 years (incremental advancement in each taxonomy).
Duration	
Teaching and learning strategies	Activist / pragmatist styles preferred.
Consideration of learning styles	Progressive use of facilitation, organising.
Teachers role	Correlated to taxonomy levels 1-3
Teaching methods	Participation and discovery styles preferred.
Learning methods	
Assessment strategies	Knowledge based initially, leading to self-sufficiency and metacognition
Assessment strategy	Formative but combined with external formal assessment
Frequency	
Resource planning and acquisition	Appropriate to remainder of proposal.
Management of the course	
Location of delivery	College and work based.
Management / organisation	Facilitation.
Curriculum organisation	Correlation to needs to industry and student. Modular and differentiated.
Monitoring and evaluation	
Guidance and counselling	Equality of opportunity and experience.

APL /APEL

Progressive achievement through each domain. Year 2 contains more use of facilitation and student reflection.

Common customer requirements	Common design requirements (modules)
Numeracy	Business management
Team working	CAD
Quality management	Engineering design
Business awareness	Engineering drawing
Commerce and profit focus	Environmental management
Drive and confidence	Group activities
Customer focus	Key skills
Logistics and supply management	Materials
Manufacturing technology	PLC's
Innovative thinking	Mechanical lab work
Communication skills	Projects
Project management	Project management
Practical craft skills	Quality management
	Software design
	Welding
	Workshop practices
	Work placements
Common to at least two quadrants	
Sustainable materials	
End of life management	
Problem solving	
Ability to exploit IT	
Time management	
Integrity	
Leadership	
Product development	

Competency	Business module (double weighting)
Numeracy	Business management
Quality management	Environmental management
Business awareness	Quality management
Commerce and profit focus	
Logistics and supply management	
Customer focus	

Competency	Maths module
Numeracy	Basic numeracy
Problem solving	Key skills application
	Higher mathematical ability

Competency	Design module
Numeracy	CAD
Team working	Engineering design
Business awareness	Engineering drawing
Innovative thinking	
Communication skills	
End of life management	
Ability to exploit IT	
Product development	

Competency	Practical applications module
Numeracy	Software design /PLC's
Communications skills	Welding
Practical craft skills	Workshop activities
Problem solving	

Competency	Science module
Numeracy	Mechanical science
Communication skills	Electrical science
Problem solving	Mech / elec labs

Competency	Work placement module
Team working	Business management
Business awareness	Group activities
Commerce and profit focus	Workshop practices
Customer focus	
Communications skills	
Problem solving	
Leadership	
Integrity	
Time management	

Competency	Projcet module (double weighting)
Numeracy	
Team working	
Business awareness	
Commerce and profit focus	
Innovative thinking	
Communication skills	
Problem solving	
Ability to exploit IT	
Time management	

Competency	Key Skills modules (double weighting)
Numeracy	Commuications , AoN, WWO, Ps , IOL Levels 1,2 and 3 covered over a two-year period
Team working	
Drive and confidence	
Communications skills	
Problem solving	
Ability to exploit IT	

Competency	Matls and Manuf module
Sustainable materials	Environmental management
End of life management	Materials
Manuf technology	

Preferred learning methods	Preferred assessment methods
Projects	Activity / formative
Group work	Assignment / formative
Case studies/ assignments	
Practical exercises / work placement	
Observations	
Role play / games	
Demonstrations	
Lectures	

Figure 8.11 Final curriculum proposal.

CHAPTER 9

CONCLUSIONS

This chapter is used to reflect upon the devised curriculum design method. Discussion is broadly aligned to reflect the original aims of the work and initially discussions and conclusions from previous chapters are reviewed against these aims. Subsequently, the significance of this study is discussed, limitations of the study are explored and areas for further work are suggested. Finally, conclusions drawn from the study are listed.

9.1 Aim 1 - The development of an integrated curriculum design method.

Chapter one established the requirement for appropriately designed and deliverable curricula within the area of engineering education. Deficiencies in existing provision were discussed and it was concluded that the needs of employers and employees alike are not being met by existing curriculum design methods. Areas for concern relating to low workforce productivity, inadequate provision for the development of technical, vocational and generic skill areas, insufficient contextualisation of study and the wider development of students where cited. Comparing existing vocational education against general education provision highlighted the impact of ideology on the curriculum design process and the selection of curriculum features. Prescriptive, descriptive and critical-exploratory curriculum theorising methods were subsequently considered and concluded to be essentially methodical in approach and therefore viewed as analogous to many well established TQM continuous improvement methods. Recurrent issues relating to an inability to satisfy customer requirements were highlighted. An hypothesis was offered that within the curriculum design process the issue confronting curriculum design is one of quality management in that providers must know how to: (1) anticipate and understand customer requirements and (2) translate and satisfy these customer requirements into a deliverable curriculum package. It was proposed that an opportunity to synthesize elements of curriculum design and quality management offered an opportunity to overcome deficiencies in supply.

Chapter two was used to further explore existing curriculum design practice. Specifically in relation to post-compulsory vocational education evidence was provided for the increased importance of instrumentalism and a competency-based approach in which the delivery of a curriculum is associated with the development of the workforce. Established curriculum design models were explored and it was proposed that the philosophical perspective of the competency-based ideology is in accord with a prescriptive approach to curriculum design as typified by the Tyler's four-stage approach to curriculum design. However, it was argued that through over-emphasizing behaviorist principles the competency model fails to adequately address logical, expressive and analytical abilities. Particular deficiencies with this approach were identified including the inadequate development of higher level skills within the affective and cognitive domains of learning, poor provision for the development of creativity and the application of theory to new situations. It was concluded that the competency-based approach to curriculum design fails to demonstrate a holistic perspective of learning and that clarity in implementation comes at the expense of producing a curriculum which is narrow in terms of cognitive and affective outcomes.

The basic purpose of post-compulsory engineering education is primarily to adequately equip students with appropriate vocational, occupational and generic skills and assist employers in raising economic performance. However, it was argued that a narrow, mechanistic and outcome-based approach to learning is counter-productive to this overall aim and that across the entire learning cycle the competency-based approach to education limits student development. A student-centred approach was therefore identified as desirable and it was hypothesized that the development of the new curriculum design method would need to allow for the incorporation of elements of both the competency-based and progressive approaches to curriculum design.

To provide flexibility and sophistication in the curriculum design process the synergy of appropriate quality management techniques and curriculum design was explored. Opportunities were shown to exist for the integration of PDCA and a process-driven approach to curriculum design. Advantages offered for the use of PDCA included its ability to produce qualitative curriculum features and its dynamic capability to reflect diversity and changes in demand. Accepting the voice of the customer was identified as being of paramount importance and the proven technique of QFD was proposed as a means of translating customer requirements into meaningful deliverables.

Chapter three was used to develop and justify the final curriculum design method. An innovative five-stage approach based on PDCA and incorporating a two-phase application of QFD was hypothesised. The incorporation of QFD was considered to be particularly relevant in relation to curriculum design as it enhances the status of the customer and shifts educational provision towards a more commercial perspective. This was viewed to be in accord with the ideological standpoint of current vocational education provision but also offer sufficient flexibility in use to allow curriculum designers to reflect their own philosophical perspective and the raison d’être of the course. Thus, it was envisaged that relevant educational objectives (ability domains) could be established within a complementary semantic structure and this was proposed as a major advantage of the devised method. A coherent curriculum design method was therefore established and the first aim of this thesis has been successfully met (see figure 9.1).

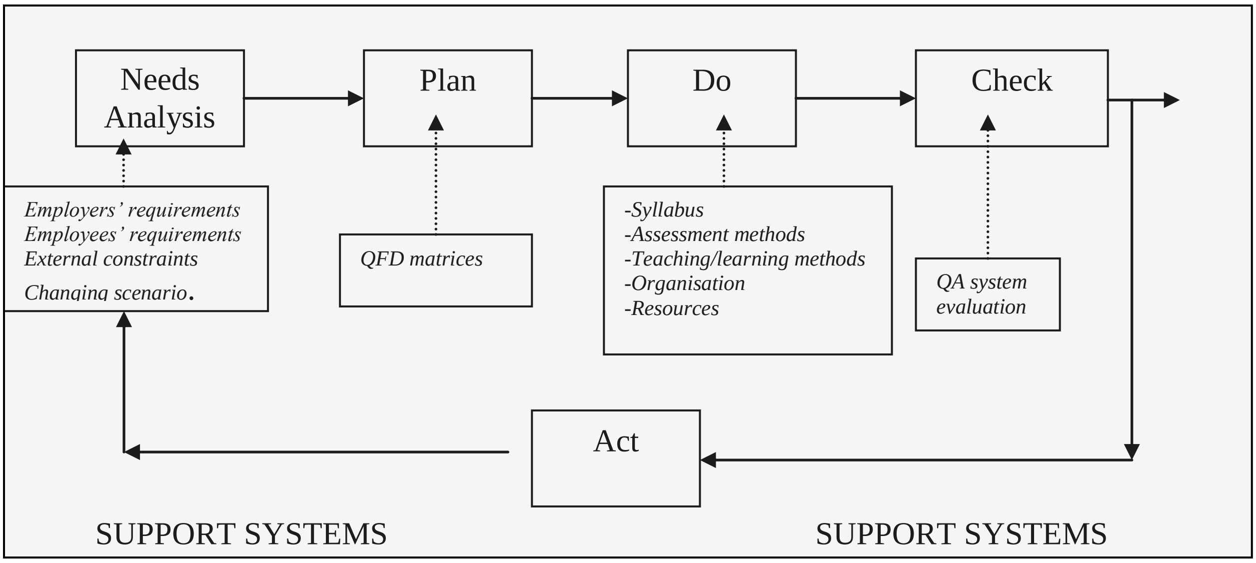

Figure 9.1 The devised curriculum design method.

Proposed advantages in the use of the devised method (as compared to existing practices) included:

- Its ability to provide providers of education with a flexible and practical, process-lead framework for curriculum design which is sympathetic to current practice.
- Its capacity for dynamic modeling to allow for evolving practices and concerns.
- Its ability to shift curriculum design to a more commercial realization.
- Its ability to provide curriculum planners with a fully justifiable explanation of curriculum features.

9.2 Aim 2 - Practical application of the curriculum design method.

Although acknowledging the primary purpose of vocational education is to contribute to business success and economic growth it was recognised that this can not be satisfied at the expense of disaffected employees. It was proposed that only through the design of a curriculum that emphasises the development of transferable personal, social, technical and generic skills, delivered in a relevant and appropriate manner, that the educational requirements of engineering industry can be satisfied.

This thesis therefore sought to use the curriculum development method to construct a curriculum profile to raise industrial performance but in a manner complementary to personal (student) growth. Application of the final curriculum proposal was specifically in relation to the education of 16-18 year olds and a range of engineering companies within the South Wales region and the research methodology used is shown in figure 9.2.

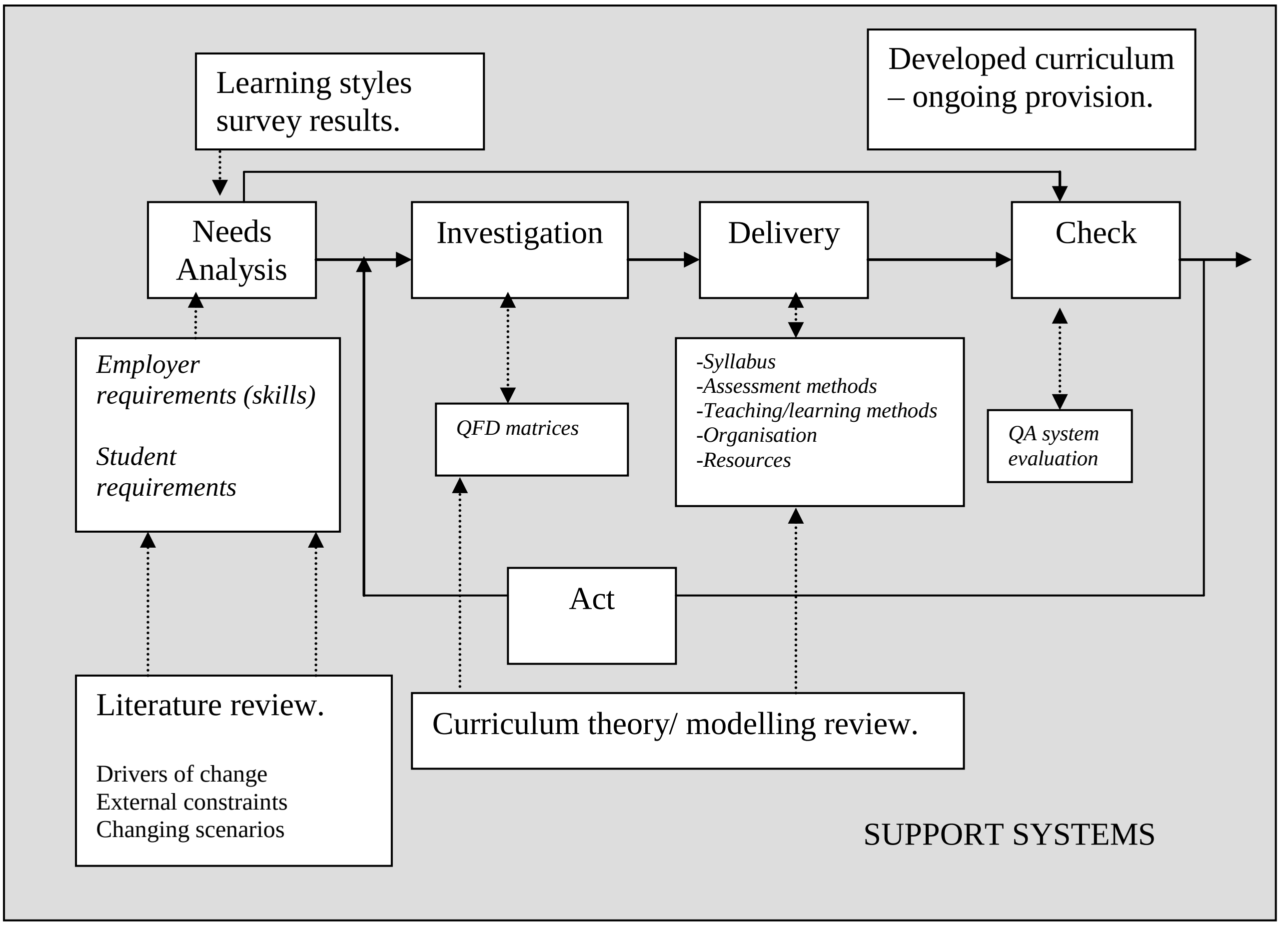

Figure 9.2 The research methodology.

The needs analysis was used to establish the requirements of both employers and students and was completed in four stages. Firstly, chapter 4 was used as an interpretive reflection of the drivers of change impacting on the engineering industry within the UK. Classifying the drivers of change as economic, occupational and technological effectively allowed for the construction of an historical perspective and forecasted scenarios to be adequately investigated. Objective (a) - to identify the key economic, technological and occupational drivers impacting on engineering companies within the UK, was therefore satisfied (see table 4 vi).

Secondly, using the output of chapter 4 (key economic, technological and occupational drivers impacting on engineering companies within the UK) chapter 6 established a complementary listing of competencies. Specific competencies classified as technical, professional and business, information handling or generic were established. Thus, objective (b) - to determine a suitable competency profile with respect to the education of 16-18 year olds was successfully completed (see chapter 6.1). The relative importance of each these competencies was subsequently tested and confirmed through research conducted with a range of engineering employers relevant to Coleg Sir Gâr (ref objective c). Findings indicated that the competencies required by employers were highly influenced by market sector (see fig 9.3). Companies operating in a market characterized by high business uncertainty and high product complexity valued information handling skills most highly followed by generic skills, technical skills and finally professional skills. Companies operating in a market characterized by low business uncertainty and high product complexity valued professional skills most highly followed by technical skills, generic skills and finally information handling skills. Companies operating in a market characterized by low business uncertainty and low product complexity valued technical skills most highly followed by professional skills, information handling skills and finally generic skills. A quantifiable profile of skills required by each area of engineering activity considered was therefore established and this data formed the input (the customer requirements) to the QFD product matrix (see chapter 8).

Business Uncertainty	High Product complexity	Low Product complexity
High	1. Information handling skills 2. Generic skills 3. Technical skills 4. Professional skills	
Low	1. Professional skills 2. Technical skills 3. Generic skills 4. Information handling skills	1. Technical skills 2. Professional skills 3. Information handling skills 4. Generic skills

Low High → Low

Product complexity

Figure 9.3 The Puttick Grid - profile of required skills.

Thirdly, in order to determine suitable features for the final curriculum proposal, chapter 5 reviewed established curriculum planning methods and learning theory (ref objective d). With regard to existing educational provision evidence was gathered to demonstrate the widespread use of behaviorist and cognitive learning theories within the delivery of engineering courses. Consequences of this approach were viewed to result in learning which is largely sequential, hierarchical, externally motivated and in which testing is used to demonstrate learning. This approach had already been identified as undesirable and within chapter 5 the fusion of elements of cognitive, humanist and constructivist perspectives was offered as advantageous. Thus, an essentially social-constructivist model was developed and justified (see chapter 5.6). Alternative assessment strategies were also reviewed and the most appropriate were considered to be in accord with a social-constructivist approach and the stated purpose of the learning. Appropriate curriculum characteristics for incorporation into the final curriculum proposal had therefore been identified and justified (see table 5 vi) and thus objective (d) was successfully completed.

To allow for an evaluation of the effectiveness of existing engineering educational provision (in comparison with the final curriculum proposal) chapter 5 was also used to investigate a range of awards (within the 16-18 year age group in Wales) and the existing Modern Apprenticeship framework within Wales (ref objectives f and g). Comparing vocational to general education differing philosophical foundations were confirmed. Vocational awards were viewed as a form of instrumental education where the overriding aim is to raise economic performance. General education was considered as more liberal than vocational education and an egalitarian emphasis is placed on democratic participation. It was concluded that the vocational route does not fully satisfy the wider humanist elements of the curriculum. In this regard it was argued that that general education (if adopted in a constructivist, liberal manner) is better able to develop wider generic skills in students. It was proposed that greater effectiveness of the vocational model can be achieved by assimilating these features, especially with regard to considering how theory and practice can be combined in a creative manner and applied to a new situation or context. Thus, greater emphasis on the use of elements of general education would be beneficial in provided for the progressive development of wider personal, social and generic skills - a point highlighted within the final curriculum proposal.

The UK apprenticeship framework is also noted to be heavily dependant on the competency-based model. Similar conclusions as those established for vocational education as a whole were therefore drawn. The laissez-faire approach used in the UK was considered to prevent holistic development of apprentices. In particular, it was concluded that the use of standard-setting and specifications must not replace but underline the importance attached to ensuring a student can understand why a task is performed and not just how a task is performed.

Fourthly, chapter 7 was used to present the results of two student surveys which were conducted to ascertain the requirements of the current engineering student cohort at Coleg Sir Gâr (ref objective e). The first was a general survey used to investigate the preferred learning and assessment methods of the students. Also investigated were the professional and personal aspirations of the students, the level of correlation between student and employer expectations and student recruitment issues. The second survey was used to investigate the preferred learning styles of the students. Preferred learning methods, assessment methods and learning styles were input into the QFD curriculum matrix. Results regarding the professional and personal aspirations of the students, the level of correlation between student and employer expectations and student recruitment issues were used to augment and improve the final curriculum proposal.

Chapter eight completed the two-phase application of QFD and the construction of the final curriculum proposal. Firstly, for each quadrant of the Puttick grid and using the results from the employer survey a product matrix was developed. The output of each product matrix was the identification of prioritised competencies and complementary curriculum design requirements (modules to be taught). Subsequently, a second matrix - termed the curriculum matrix was developed. The purpose of the curriculum matrix was to allow for the construction of the final curriculum proposal. This was not only complementary to the requirements of engineering employers but also factored in complementary learning, teaching and assessment strategies. In conjunction with the salient curriculum features (table 5 vi) the amalgamation of the different curriculum matrices into a single curriculum proposal was therefore completed. The final curriculum proposal is discussed in chapter 8.3.1

9.3 Significance of the study.

The aim of this research was to develop an integrated curriculum design method and practically apply it in the design of an appropriate curriculum proposal for the provision of engineering education at entry level (within the 16-18 year age group). The core work was to apply the developed method to vocational engineering educational provision in relation to a range of selected engineering companies within the South Wales region. This was justified due to the nature of the work of the author as a tutor within Coleg Sir Gâr. By concentrating on the requirements of these companies it was possible not only to illustrate the effectiveness of the curriculum design method but also to produce a specific output relevant to the author and his employer.

The significance of the thesis is two-fold. Firstly, it has established a new and integrated process-based mechanism for curriculum design which can accurately establish and satisfy the requirements of individuals and employers. Specifically it innovatively integrates PDCA, QFD and established curriculum design theory to allow for an appropriate and effective curriculum proposal to be established. It is envisaged that the curriculum design method will be of practical value to the designers of curricula. It is intended that when used in conjunction with employers, employees and academic institutions the method will assist in the appropriate development of young people and help to equip them with the vital skills which are required in a globally competitive market. Flexibility in application has been recognised and the method devised will allow for the requirements of Small and Medium size Enterprises as well as large national and multinational organizations. Furthermore, the method has been designed to be adaptive and flexible to organisations across a variety of sectors, products and customers.

Secondly, in relation to a range of engineering companies within the South Wales region, the application of the curriculum design method has provided for a curriculum proposal to be constructed. The proposal has been constructed with characteristics complementary to the competencies required by these companies and incorporates the most suitable teaching, learning and assessment methods to maximise the development of the students. This is valuable information for those concerned.

The results of this study have been presented to SEMTA and recognition of its significance has been made (see appendix 3).

9.4 Limitations of the study and areas for further work.

Development of the curriculum design model.

The effectiveness of the curriculum design method could be enhanced by further consideration of the relationship between customer requirements and curriculum features. In particular, efforts to avoid the dilution of data and an ability to further establish and understand the complex relationship between customer requirements and curriculum features should be considered. In this regard areas for development would appear to include the possible use of force-field analysis, customer contingency tables and focus groups at the needs analysis stage. At the investigation stage the possible use of benchmarking and FMEA should be considered and similarly at the check and act stages it would be possible to include methods such as quality costing or tools such as control charts for problem prioritisation and analysis. Specifically in terms of using QFD, opportunities for avoiding the dilution of customer requirements appear to be available through enhanced customisation of the product and curriculum matrices. In particular, by further refining and categorizing customer requirements a greater understanding of the complex interrelationships between supply and demand will be gained.

Data accuracy is critical to success in using the devised curriculum design method. Although practical implementation prevents the exhaustive collection and analysis of data, careful consideration should be given to appropriative sample sizes. The sample sizes used in this study were small and only concerned provision relating to Coleg Sir Gâr. Consideration on how to extending the study to other colleges and obtain a greater sample size should be given.

Application of the curriculum design model.

In keeping with the accepted TQM approach of investing in people to deliver quality this thesis has not recommend a centralised top-down approach to the implementation of the curriculum design method. Mechanisms must be found to ensure that lecturers and support staff are encouraged to take ownership of the curriculum. It is critical in any implementation process to gain staff commitment and it is likely that within an education environment the attitudinal disposition if individuals will be a key element in the success or otherwise of the implementation process. The curriculum design method should not be perceived as institutionalised and instead staff must be involved in its dynamic evolution and enactment. In practice this could include the inclusion of key staff at the curriculum design stages and an ongoing emphasis on staff development (such as the appointment of change champions).

In particular, greater effectiveness could be gained by considering how a multi-disciplinary team consisting of management, teaching and support staff can be incorporated in to the design process.

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Appendix one

QUESTIONNAIRE FOR INDUSTRIALISTS

Dear sir/madam,

I am currently completing research into the effectiveness of engineering education with the UK. As part of this research I am canvassing opinion from professionals currently working in engineering industries as to what they perceive to be the current and future requirements for engineering education.

In order to gather information on this important subject I would be grateful if you would complete the following questionnaire. All data will be treated as confidential and presented in a way that will not allow identification of your individual answers.
Thank you for your time in completing this form.

Chris Davies (Lecturer – Coleg Sir Gâr)
Tel : 01554 774089 e-mail: chris.dav@colegsirgar.ac.uk

Section one: Company Information.

Please tick the boxes as appropriate.

Personal details	**Employer details**
Gender ☐ Male ☐ Female	**Company name (and group name if applicable):**
Age: ☐ less than 30 ☐ 30-45 ☐ more than 45	**Total number of employees at your site:**
Job title:	**Approximate company turnover:**

Section two: Manufacturing Competencies.

It is important that we establish the current and future competencies required within your company and engineering organisations generally.
The following tables list a series of competencies, which you may or may not consider to be important. Please tick a number to rate what you consider to be the importance of each competency

(1= not important to 4 = very important).

Competence	**Today**				**In 5 years time**			
Overall Rating	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Technical								
Professional and Business								
Information handling								
Generic Skills								
Other (please specify)								

Technical	Today				In 5 years time			
Rating	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Product development								
Advanced CAD/CAM								
Practical craft skills								
Manufacturing technology								
Material flow								
Cleaner production								
Sustainable manufacture								
Project management								
End of life management								
Logistics and supply management								
Quality Management								
Other (please specify)								

Professional and Business	Today				In 5 years time			
Rating	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Business awareness								
Commercial and profit focus								
Customer focus								
Business development								
Persuasiveness								
Drive and confidence								
Presentational skills								
Other (please specify)								

Information handling	Today				In 5 years time			
Rating	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Numeracy								
Ability to exploit IT								
Higher Mathematical ability								
Problem solving								
Innovative thinking								
Other (please specify)								

Generic Skills	Today				In 5 years time			
Rating	1	2	3	4	1	2	3	4
Leadership								
Team working								
Creativity								
Communication skills (verbal and written)								
Project Management								
Multicultural skills								
Time management								
Integrity								
Building relationships								
Other (please specify)								

Thank you for taking the time to complete this questionnaire.

Appendix two

QUESTIONNAIRE FOR STUDENTS

Dear student,

I am currently completing research into the provision of engineering education within the UK. As part of this research I am canvassing opinion from students as to what they perceive to be the issues of current and future concern.
In order to gather information on this important subject I would be grateful if you would complete the following questionnaire. All data will be treated as confidential and presented in a way that will not allow identification of your individual answers.
Thank you for your time in completing this form.

Chris Davies (Lecturer – Coleg Sir Gâr)
Tel :01554 774089 e-mail: chris.dav@colegsirgar.ac.uk

Section one: about yourself.
Please tick the boxes as appropriate.

Gender: ☐ Male ☐ Female

Age: ☐ less than 16 ☐ 16-18 ☐ 19-25 ☐ more than 25

Current course: ☐ NVQ Level 1 or 2 ☐ National Certificate ☐ HNC ☐ National Diploma ☐ HND ☐ BSc ☐ Other

Please specify your engineering discipline (e.g. Mechanical, Electrical, etc)………………….

If other, please specify…………………………………………………………………………….

Mode of study: ☐ Full time ☐ Part time

If you are employed as an apprentice please also complete the following section.
Please confirm the year of apprenticeship you are currently in:
Name of employer:

Section two

1. Please state the main reasons why you decide to take up engineering as a career (tick as appropriate).

Interested in practical work	
Looking for an apprenticeship	
Influence of family or friends	
Advice from careers teachers	
Disappointing exam results	
Desire to help society	
Desire to be creative/enjoyment of problem solving	
I like working on cars	
Desire for a career change	
Good at math's and sciences	
Financial rewards available	
Good employment prospects	
Good career development opportunities	

2. Would you recommend engineering as a career?

Yes	
No	
Don t know	

If yes, please indicate the main reasons why you would recommend engineering as a career.

Challenge	
Pay	
Satisfaction	
Status	
Excitement	
Other (please specify)	

3. How much do you agree or disagree with the following statements about engineering?

(1= strongly agree to 4 = strongly disagree).

Agree → Disagree

	1	**2**	**3**	**4**
It is boring				
Good wages/salary				
Dirty working environment				
Interesting work				
Need to be clever to do engineering				
Secure job				
Working in teams				
A job mainly for men				

4. The following statements can be used to describe engineers. How much do you agree or disagree with them.

(1= strongly agree to 4 = strongly disagree).

Agree ⟶ Disagree

	1	2	3	4
Intelligent				
Logical				
Methodological				
Male/Mostly male				
Responsible				
Rational/Logical				
Enquiring				
Largely funded by industry				
Objective				
Independent				
Friendly				
Socially responsible				
Honest				

5. How far do you intend to pursue a career in engineering? Below is a list of possible qualifications and occupational levels.

Please indicate what you considered to be your targeted level.

Qualification	**Please tick appropriate box**	**Occupational level**	**Please tick appropriate box**
NVQ 2 / ONC / OND/ City and Guilds		Craft person	
ONC/ OND		Technician	
HNC / HND		Higher technician	
Degree		Professional engineer	

6. I am on this course because (tick as appropriate).

Objective	
I want an apprenticeship	
I want to get employment	
I want to get employment (within engineering)	
I want to get into Higher education	
I wanted to get better qualifications	
Because there was nothing else to do	
I want to get into the armed forces	
Other (please specify)	

7a. (Full-time students only)

What areas of your current programme of study have you found of greatest interest? *(Tick as appropriate).*

Business Management	☐	Key skills	☐	Quality Management	☐
CAD	☐	Instrumentation & control	☐	Software design	☐
CAM	☐	Materials	☐	Welding	☐
CNC	☐	Mathematics	☐	Working on Computers	☐
Electronics	☐	Mechanical science	☐	Workshop activities	☐
Electrical Principals	☐	Mechanical Laboratories	☐	Work Placements	☐
Electrical Installation	☐	PLC's	☐		
Engineering Design	☐	Pneumatics and Hydraulics	☐	*Other (please specify)*	
Engineering Drawing	☐	Primary / Secondary Processing	☐		
Environmental Man'ment	☐	Project	☐		
Group activities	☐	Project Management	☐		

7b. (Employed students only)

What areas of your current programme of study have you found of greatest relevance to your work? *(Tick as appropriate).*

Business Management	☐	Key skills	☐	Quality Management	☐
CAD	☐	Instrumentation & control	☐	Software design	☐
CAM	☐	Materials	☐	Welding	☐
CNC	☐	Mathematics	☐	Working on Computers	☐
Electronics	☐	Mechanical science	☐	Workshop activities	☐
Electrical Principals	☐	Mechanical Laboratories	☐	Work Placements	☐
Electrical Installation	☐	PLC's	☐		
Engineering Design	☐	Pneumatics and Hydraulics	☐	*Other (please specify)*	
Engineering Drawing	☐	Primary / Secondary Processing	☐		
Environmental Man'ment	☐	Project	☐		
Group activities	☐	Project Management	☐		

7c. If there any other areas of study you would wish to see on the programme?

8. Please indicate below what are your preferred methods of learning (tick as appropriate).

Group working	
Practical activities	
Lectures	
Video	
Problem solving	
Role playing	
Note taking	
Handouts	
Work placements/ real life activities	
Other (please specify)	

9. Please indicate below your preferred methods of assessment (tick as appropriate).

Assignments	
Examinations	
Observations	
Criteria based assessments	
Peer assessment	
Class tests	
Other (please specify)	

10. Please rate which of the following skills you think you will need in the future.

(1= strongly agree to 4 = strongly disagree).

Agree → Disagree Agree → Disagree

Competence	**Today**				**In 5 years time**			
Overall Rating	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Technical								
Business								
Practical skills								
Information handling								
Key Skills								
Other (please specify)								

x

Appendix three

Feedback on:	A presentation given by Chris Davies (Coleg Sir Gar)
Subject:	The Development and Application of an Integrated Curriculum Design Method
Feedback Author:	Ken Toop, Sector Skills Advisor SEMTA
Presentation date:	20.04.2007

Foreword

Change drivers i.e. economic, technological, environmental etc, impact on every aspect of our lives and in most cases we react and adapt to the result of such change. In Industry such change can have a dramatic impact on both the sector (supply chain) and the community that supports it.
Change drivers can act positively as well as negatively depending on the approach taken to change by the organisation, community or sector.
A proactive approach to change can be seen in Industry across sectors and is usually marked by increased market share, increased profitability and expansion of operations although there are some exceptions to the latter.
Learning methodology predates many of the changes drivers we are aware of, although examples of new approaches are prevalent in some progressive organisations.
Therefore the need to integrate curriculum design in a more proactive, industrial learner driven manner would seem appropriate in a very change driven sector.

Presentation Feedback

A well balanced presentation showing the rational, provision, aims and objectives, methods, stages of research, results and findings.
The rational backed by findings on UK competitiveness and educational provision coherently set the scene for the project aims and objectives.
Effective use was made of a plan, do, check, act cycle in terms of methodology and research carried out on generic drivers of change was clearly cross-referenced.
The employer survey provided a good insight into the companies involved as did the student survey in terms of their learning preferences and it was noted that not all learning preferences are suitable and a certain amount of logic and experience must be applied to this process.
The QFD results clearly identified how the companies involved in the research were served by the delivery of the existing curriculum and where gaps and over emphasis had emerged.
The second matrix looked at the learner and established a curriculum profile to accommodate both industrial and student needs i.e. focused and profiled learning provision.
The presentation covered existing delivery in a concise and categorised manner identifying key issues and approaches taken. The resulting salient features clarify the characteristics that are needed in the final proposal and contextualise the reasoning, which was graphically illustrated in the final curriculum proposal The final slide on the presentation illustrates clearly the vocational and academic attributes associated with existing learning provision and how a balance of clearly defined and profiled attributes are required to deliver world class skills and productivity. It is critical that we adapt to industrial, economic and social change in a positive proactive manner, learning provision needs to be effectively and accurately profiled against drivers of change. The presentation provided a clear and detailed insight into how profiling and modelling learning provision can be used against industrial, economic and social change which in turn could improve not only the industrial application of learning but also national standards of achievement and learner esteem.

Appendix four

UNIVERSITY OF GLAMORGAN
PRIFYSGOL MORGANNWG

SCHOOL OF TECHNOLOGY

Research Application Approval by the School's Ethics Committee

N.B. All questions should be addressed.

---

1. **Name of Applicant**

Christopher Mark Davies

2. **Duration of Research (over what period of time do you wish approval to be granted?)**

2003-2008

3. **Design of the Research Methodology(describe briefly – maximum 250 words)**
Questions to ask:
Does the ethics statement reflect the research methodology?
Is the confidentiality of research at risk of being compromised by dependence on a sponsor or an institution with particular interests?

All work conducted as part of this research will be completed in accordance with the requirements of the University's Policy on Ethics in Teaching and Research and Non-Specialist Ethical Guidelines for Research. The following statement has been written after careful consideration of the research methodology detailed within the proposal document.

Specifically with regard to the above it is anticipated that the following ethical issues will need to be addressed:
- *Respecting the autonomy of all participants.*
- *Informed consent of all participants.*
- *Confidentiality and Anonymity of individual participants and their employers/ organisations.*
- *Give equal consideration to the interests of everyone.*
- *Carry out research with integrity.*

A Detailed consideration of ethical issues follows.

It is anticipated that throughout the project it will be required to canvass opinion and obtain recommendations from a variety of people and organisations from within the engineering sector. Clearly it will be necessary to explain the purpose of the research to these individuals and ensure that explicit permission is obtained for their contributions to be included in any published documents as well as the final thesis. Every effort will be made to ensure that informed consent is gained and that practices and methodologies, which involve deceit, dishonesty, invasion of privacy or breaking confidentiality, will be avoided.

Specifically it will be ensured that all participants are made aware of the aims of the research, the possible consequences of the research, how the results are to be disseminated and all the likely disclosures of personal data. No covert research will be conducted and no research findings will be divulged to other researchers. The anonymity and privacy of research participants will be respected and personal information relating to participants will be kept confidential and secure. Every effort will be made to anonymise the personal data such that it would not be possible for the University, its staff or students or the researcher, to identify the individual from that data and any other data held.

No individual or organisation will be treated with undue regard or preconceived consideration. This it is anticipated will safeguard the rights of all participants as well preventing the research itself being undermined. It will be ensured that the objectives of all parties are clearly articulated at the outset, and that the research is set up in such a way that it is independent of any special interests.

The confidentiality of research is not at risk of being compromised by dependence on a sponsor or an institution with particular interests

4. Investigative Procedures

Questions to ask:

What investigative procedures do you intend to carry out, if any (eg interviewing, questionnaires etc)?

It is anticipated that the majority of research will involve quantitative data gathering from traditional sources within the public domain. To augment this information it expected that a series of interviews would be held with relevant people and organisations (e.g. students, employers and academics). To ensure consistency and balance it is expected that this information will be recorded on a questionnaire and be stored on a computer.

4.1 From Whom and Where will data be Gathered?

See above and question 6 below.

5. Informed Consent

If you have any doubt about whether or how informed consent can be obtained, you will need to discuss this with a member of the Committee in the first instance.

A. The submission should be specific about the following:

i. Will consent be given in written form? (a copy of any consent form should be attached).

It is not anticipated that written consent will be required in the vast majority of cases. If personal or commercially sensitive information is sought then written consent will be requested (see attached consent form, Re: appendix 1).

ii. How will subjects be given information about the study? (a copy of the information sheet, whether it is to be read out or given to the subject, should be attached).

All subjects participating in the study will receive a copy of the research proposal as well as a signed declaration on the confidentiality of the information obtained.

iii. How will the subject or volunteer be asked to participate?

It is anticipated that the majority of volunteers will be asked to participate in writing although in some instances a verbal request may be initially made. Verbal requests will be followed up with a written request, which will also contain details of the research proposal as well as a signed declaration on the confidentiality of the information obtained.

iv. How much time will be allowed for subjects to consider and consult others before giving consent?

Due to the nature of the research proposal no formal time restraint is considered appropriate.

v. If the study includes people who may be unable to give informed consent, what alternative process will be used?

N/A

B. What will the subject be told about:

i. the project and what it is intended to show

Covered by the research proposal as well as a signed declaration on the confidentiality of the information obtained.

ii. the frequency of procedures and what they entail

N/A

iii. possible risks and side effects

N/A

iv. entitlement to leave study.

Covered by the research proposal as well as a signed declaration on the confidentiality of the information obtained.

6. **Computers**

Are computers to be used to store data? **YES** / NO

If so, is the data registered under the Data Protection Act? YES / **NO**

7. The information supplied above is to the best of my knowledge and belief accurate.

I understand that I may be invited to explain my proposal to the Committee.

I understand that the School Ethics Committee gives ethics approval only.

SIGNATURE OF INVESTIGATOR C.M.Davies. C.M.Davies

DATE OF SUBMISSION 28/06/03

Notes for guidance on completing this form

The University's ethics approval procedure for research proposals is as follows:

Research proposals must be approved by a School Ethics Committee before the work begins. When appropriate and possible, ethical aspects of a research proposal will be considered by a research committee, research unit or Field before it is sent to a School Ethics Committee. However it may appropriate for some proposals - eg for individual staff research projects - to go direct from the originating member of staff to SEC.

Proposed research activities include newly planned student research projects and newly-planned staff/postdoctoral research projects.

Please use this form to submit research proposals to School Ethics Committees. Before completing it, please read the University's publications Guide to Ethical Issues in Teaching and Research and Non-specialist Guidelines for Research as well as any relevant subject specific guidelines.

If a proposal is considered by a research unit or committee before it is submitted to SEC, the head of the research unit or committee should sign the form as the proposer, indicating his or her position. If the proposal is not considered by research unit or committee, the proposer is the member of staff who originates the proposal.

Once a research proposal has been approved by a SEC and put into operation, the day-to-day responsibility for monitoring the ethical aspects of the project rests with its director of studies.

Appendix 1 – Research Consent Form

Title of Project Research: A critical analysis of educational strategies within the engineering manufacturing sector.

Work Conducted by: C.M.Davies (Tel 01554 748049)
(e-mail: chris.dav@colegsirgar.ac.uk)

The following section should be completed by the research subject

	Yes	No
Do you understand that you have been asked to be in a research study?		
Have you received and read a copy of the proposed research proposal?		
Do you understand the risks/benefits in being involved in this research?		
Have you had an opportunity to ask questions about this research?		
Do you understand that you are free to withdraw from this study at any time?		
Have the issues of confidentiality been explained to you?		

I agree to take part in this study.

Signed:

Date:

Confidentiality statement

Use of your personal information: Information about you or your business may be required for this research. The researcher will not use your personal information except in relation to this research project and will maintain the confidentiality of your information at all times.

The anonymity and privacy of research participants will be respected and personal information relating to participants will be kept confidential and secure. Every effort will be made to anonymise the personal data such that it would not be possible to identify the individual from which that data was obtained.

Information received will not be not sold, rented or leased to third parties. Nor will information received be disclosed if it is sensitive personal information, such as race or religion, without your explicit consent.

Security of your personal information: The researcher undertakes to secure any personal information you have provided on computer in a controlled, secure environment, and protect that information from unauthorised access, use or disclosure.

Data Protection Act: The researcher undertakes to collect and use your personal information in compliance with the Data Protection Act. You have a right to ask for a copy of the information being held on you at any time and to have that information corrected if it is inaccurate.

Signed :

C.M.Davies.

Appendix five

Unit No	Title	Level	Assessment Mode
1	Engineering Material, Processes and Techniques	AS	External (Examination)
2	The Role of the Engineer	AS	Internal (Coursework project)
3	Principles of Design, Planning and Prototyping	AS	Internal (Coursework project)
4	Applied Engineering Systems	A2	External (Examination)
5	The Engineering Environment	A2	Internal (Coursework project)
6	Applied Design, Planning and Prototyping	A2	Internal (Coursework project)

GCE AS / A level award in Engineering.

Unit No	Title	Level	Assessment Mode
1	Core Mathematics C1	AS	External (Examination)
2	Core Mathematics C2	AS	External (Examination)
3	Core Mathematics C3	A2	External (Examination)
4	Core Mathematics C4	A2	External (Examination)
5	Further Pure Mathematics FP1	A2	External (Examination)
6	Further Pure Mathematics FP2	A2	External (Examination)
7	Further Pure Mathematics FP3	A2	External (Examination)
8	Mechanics M1	AS	External (Examination)
9	Mechanics M2	A2	External (Examination)
10	Mechanics M3	A2	External (Examination)
11	Mechanics M4	A2	External (Examination)
12	Mechanics M5	A2	External (Examination)
13	Statistics S1	AS	External (Examination)
14	Statistics S2	A2	External (Examination)
15	Statistics S3	A2	External (Examination)
16	Statistics S4	A2	External (Examination)
17	Decision Mathematics D1	AS	External (Examination)
18	Decision Mathematics D2	A2	External (Examination)

GCE AS / A level awards in Mathematics.

Unit No	Title	Level	Assessment Mode
1	Mechanics and Radioactivity	AS	External (Examination)
2	Electricity and Thermal Physics	AS	External (Examination)
3	One Topic from astrophysics, solid materials, nuclear and particle physics and medial physics.	AS	External (Examination and practical test)
4	Waves and our Universe	A2	External (Examination)
5	Fields and Forces	A2	External (Examination and practical test)
6	Synoptic unit	A2	External (Examination)

GCE AS / A level awards in Physics.

Mechanical Engineering		Manufacturing Engineering	
Unit	Units	Unit	Units
	Core units		***Core units***
1	Business Systems for Technicians	1	Business Systems for Technicians
2	Communications for Technicians	2	Communications for Technicians
3	Science for Technicians	3	Science for Technicians
4	Mathematics for Technicians	4	Mathematics for Technicians
5	Project	5	Project
6	Mechanical Principles	6	Mechanical Principles
	Specialist units – Group A		***Specialist units – Group A***
7	Engineering Materials	7	Production Planning
8	Mechanical Technology	8	Primary forming Processes
9	Further Mechanical Principles	9	Finishing/ Secondary Processes
10	Fluid Mechanics	10	Fabrication Processes
11	Thermodynamics	11	Welding Processes
12	Elect ,Pneumatic & Hydraulic systems	12	Engineering Materials
13	Process Management	13	Measurement and Insp Tech
14	Engineering Workplace Practices	14	Engineering Drawing
15	Drawing and CAD	15	Engineering Design
	Specialist units – Group B	16	Sheet-metal Manuf using CAD
16	Measurement and Insp Techniques	17	CNC Machining
17	Computer Aided Design	18	CAM
18	Engineering Design	19	World Class Quality Techniques
19	Quality Assurance and Control	20	Electronic Circuit Manufacture
20	Health , Safety and Welfare	21	Semiconductor Processing
21	Finishing/ Secondary Processes	22	Engineering Workplace Practices
22	Primary forming Processes		***Specialist units – Group B***
23	Fabrication Processes	23	Programmable Controllers
24	Welding Processes	24	Health , Safety and Welfare
25	Testing of Welded Joints	25	Introduction to Robot Technology
26	Programmable Controllers	26	Welding Principles
27	CNC Machining	27	Testing of Welded Joints
28	Introduction to Robot Technology	28	Mechanical Principles
29	Electrical and Electronic Principles		
30	Further Mathematics		

Modules with the NC/ND's (Mechanical/ Manufacturing Eng).

Elec/ Electronic Engineering		Elec/ Electronic Engineering	
Unit No	Units	Unit No	Units
	Core units		***Specialist units – Group B***
1	Business Systems for Technicians	24	Electrical Installation
2	Communications for Technicians	25	Electrical Technology
3	Science for Technicians	26	Health , Safety and Welfare
4	Mathematics for Technicians	27	PC Specifications and

			Maintenance
5	Project	28	Introduction to Software Dev
6	Mechanical Principles	29	Introduction to Robot Technology
	Specialist units – Group A	30	Programmable Controllers
7	Electronics	31	Further Mathematics
8	Analogue Electronics		
9	Digital Electronics		
10	Further Electronics		
11	Microelectronics		
12	Electronic Fault-finding		
13	Electronic CAD and analysis		
14	Electronic Circuit Manufacture		
15	Electronic Measurement and Testing		
16	Further Electrical Principles		
17	Switchgear and Power Transformers		
18	Inspection and Testing of Low voltage Electrical Installations		
19	Three Phase Systems		
20	Three Phase Motors and Drives		
21	Electrical Applications		
22	Electrical safety and Standby Systems		
23	Engineering Workplace Practices		

Modules within the NC/ND's (Electrical / Electronic Eng).

Level 1		**Level 2**	
Unit No	Units	Unit No	Units
	Mandatory units		***Mandatory units***
1	Working safely in engineering	1	Working safely in engineering
2	Developing yourself and working with others on engineering activities.	2	Developing yourself and working with others on engineering activities.
	Optional units	3	Using and communicating technical information
			Optional units (Group A)
3	Making components using hand tools and fitting techniques	4	Identifying and selecting engineering materials
4	Engineering machining	5	Marking out for eng activities
5	Working with sheet metal	6	Applying QC in engineering
6	Working with thick plate	7	Erecting and dismantling access structures
7	Joining using welding techniques	8	Moving loads by slinging &lifting
8	Using oxy-fuel cutting equipment	9	*Optional units (Group B)*
9	Assembling electronic components	10	Using computer software packages to assist eng activities
10	Wiring electrical circuits	11	Fitting using hand skills
11	Making components from wood	12	Machining engineering materials
12	Making components by moulding	13	Maintaining fluid power systems
13	Making sand moulds and cores for casting	14	Maintaining mechanical devices and systems

14	Fettling castings	15	Forming and assembling pipework systems
15	Finishing surfaces by applying coatings or treatments	16	Assembling and testing fluid power systems
16	Carrying out routine servicing of mechanical equipment and systems	17	Installing and dismantling ancillary steelwork
17	Carrying out routine servicing of electrical / electronic equipment and systems	18	Producing sheet metal components and assemblies
18	Assembling Mechanical Components	19	Joining using welding techniques
		20	Cutting using oxy-fuel gas cutting equipment
		21	Wiring and testing electrical circuits
		22	Build and test electronic circuits
		23	Maintaining and testing instrumentation devices
		24	Using PLC based systems
		25	Using CNC machines
		26	Produce drawings using CAD
		27	Using wood for pattern/ model making
		28	Making components from composite materials
		29	Prepare sand moulds and cores for casting
		30	Producing castings
		31	Finishing surfaces by applying coatings
		32	Finishing surfaces by applying treatments
		33	Heat treating materials
		34	Maintaining elec equip and systems
		35	Maintaining electronic equip and systems
		36	Installing elec wiring systems
		37	Preparing and using ind robots
		38	Forging engineering materials
		39	Producing computer software to assist engineering activities
		40	Producing platework components and assemblies
		41	Preparing and manoeuvring aircraft on the ground

Unit structures for PEO level 1 and level 2.