THE UNIVERSITY OF WARWICK

School of Engineering

A Framework to Facilitate Effective E-Learning in Engineering Development Environments

EXECUTIVE SUMMARY

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WMG MANAGEMENT·SYSTEMS·TECHNOLOGY

ABSTRACT

The demands of the continually changing and developing workplace require individuals to be adaptable, multi-disciplined and with the ability to work collaboratively, often in virtual environments. Professional engineers of today must meet these demands and have appropriate business and communication skills to operate in today's competitive, fast-moving, global environment. Yet, these engineers still need to remain productive and routinely keep abreast of technological advances for their day-to-day working requirements. Thus, a range of continually renewable competencies is essential, which in turn puts pressure on both industry and academia to consider alternative ways to inform and educate their engineers and students. To help address these requirements, electronic learning (e-learning) has been researched as a possible solution to facilitate a more flexible, distributed, collaborative, self-directed, virtual learning environment for both work-based professional engineers and engineering students.

This research revealed gaps in both the existing literature and working practices regarding the e-learning needs of engineers and in current approaches to meet these needs. Consequently, the main objective of the research was to develop a mechanism to assist providers of e-learning to construct effective e-learning activities in engineering development environments. In this context, 'development' environments refer to the engineer's product-development environment and the engineering student's study environment, with the increasing responsibility for self-development in an engineering career. The research identified and investigated factors that affect learning in these engineering environments, and examined current Web-based technologies to support and enhance learning experiences. A framework was developed as the mechanism to group the different and non-comparable learning factors together into philosophy, delivery, management and technology categories. These learning factors can be connected and sequenced differently in the categories, depending on the learning requirements. Hence, the main research innovation has been the creation of this framework to structure, link and order key learning factors, which offers guidance to e-learning providers developing e-learning environments.

A predominant action research methodology was adopted for the research, as the author was involved with engineering environments and their e-learning practices, decisions, developments and implementations in varying degrees. The main areas investigated for the research were:

1) **Exploring learning methods & preferred learning styles in the engineering environment.** Important findings here identified that engineers have a strong visual learning style preference and practise experiential learning in their engineering environments.
2) **Examining technologies to support and enhance learning.** This provided an understanding of 'hard' computer and Web capabilities, and 'soft' non-tangible technologies. Web technologies were of particular interest to this research due to their wide reach and interactive impact on the modern working and learning environments.
3) **Investigating marketing considerations from the Web-based learning (WBL) providers' viewpoint.** Marketing issues, products and services of WBL providers were investigated. This compared what and how the market offered and identified the business aspects of WBL.
4) **Developing an e-learning framework.** The research was consolidated to create a novel framework that grouped disparate learning factors for effective e-learning development.
5) **Studying practical engineering e-learning applications.** Areas of the proposed framework were validated and refined from the case study data and experiences. Critical success factors (CSF) were derived to provide a business perspective for e-learning developments, and these complemented the framework's learning factors.

The above areas have been addressed in detail and documented in separate Engineering Doctorate submissions. This Executive Summary outlines and consolidates these areas, and describes, exemplifies and verifies the various factors within the e-learning framework and the CSFs. The rationale, applications and guidelines for the e-learning framework are also discussed. The framework provides a toolkit for building effective e-learning activities in engineering development environments. Thus, the research shows that e-learning can provide the solution to facilitate a flexible, continuous learning environment for engineers.

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LIST OF ABBREVIATIONS

3D	Three Dimensional
ADDIE	Analyse, Design, Develop, Implement and Evaluate
ADL	Advanced Distributed Learning
ARCS	Attention, Relevance, Confidence, Satisfaction
B2C	Business-to-Consumer
CAD	Computer-aided Design
CBL	Computer-based Learning
CD	Compact Disk
CMS	Course Management System
CSF	Critical Success Factor
DEST	Australia's Department of Education, Science and Training
DFA	Design for Assembly
DFM	Design for Manufacture
DFMEA	Design Failure Mode Effect Analysis
E2BM	Electronic Engineering Business Management
ECT	E-Commerce Technologies (an E2BM MSc module)
ED-MEDIA	Educational Multimedia, Hypermedia & Telecommunications
E-Lab	Electronic Laboratory (A division of the IT Services Department at the University of Warwick)
E-learning	Electronic Learning
ELF	JISC's E-learning Framework
Email	Electronic Mail
EngD	Engineering Doctorate
FEA	Finite Element Analysis
FEB	Finance for E-Business (an E2BM MSc module)
FREMA	Framework Reference Model for Assessment
GEB	Global E-Business (an E2BM MSc module)
HR	Human Resource
ICT	Information & Communications Technologies
IET	Institute of Engineering & Technology
IMS	Instructional Management System
IT	Information Technology
JISC	Joint Information Systems Committee
JIT	Just-in-Time
LMS	Learning Management System
LCMS	Learning Content Management System
MSc	Master of Science
OEM	Original Equipment Manufacturer
PMA	Post Module Assignment
PDSA	Plan, Do, Study, Act
ROI	Return on Investment
SCORM	Sharable Content Object Reference Model
SOA	Service-oriented Architecture
TBL	Technology-based Learning
VLE	Virtual Learning Environment
VR	Virtual Reality
WBL	Web-based Learning
WMG	Warwick Manufacturing Group (A division of the School of Engineering at the University of Warwick)

DECLARATION

I, **Yvette James-Gordon,** declare that all the work presented within the Executive Summary and the respective Project Submissions have been undertaken by myself, unless otherwise acknowledged or referenced within the text, and that this work has not been previously submitted for any other academic qualification.

1.0 INTRODUCTION

The demands of the changing and developing workplace require a wide range of up-to-date competencies from individuals. Consequently, this requires them to constantly renew and expand their knowledge and skills to keep themselves up-to-date and maintain their value to the organisation. To accommodate this, learning is becoming an integral part of the workplace and not just the responsibility of academia, and so the distinctions between learning and working activities are becoming increasingly blurred. Reay (1994) brings these aspects together by defining learning in an organisation as "*a collection of actions which enables the organisation to achieve its goals through enabling, empowering and developing to its fullest, the potential of the individuals within that organisation*". Whilst this is a standard definition of learning in an organisation, it makes no provision for change or continual development. The author believes that Pedler et al (1997) provides a fuller description to incorporate these aspects in a learning environment, as being "*an organisation, which facilitates the learning of all its members and consciously transforms itself and its contents*". This definition emphasises that an organisation intentionally adapts itself by recognising the need to keep abreast of change. Change, not only in the organisation and the individuals, but also in the learning content required to keep it updated. Additionally, learning in an organisation needs to provide a collaborative as well as supportive environment so that individuals are encouraged to learn and share what they have learnt with others (Dixon, 1998; Garratt, 1994, Senge 1992). All of these aspects lead to what is known as the 'learning organisation', which is considered to be a key requirement in the development of world class organisations (Senge, 1992). However, Senge (1992) also states that there needs to be an effective learning environment in place for individuals, in order for learning in the organisation to occur. Learning encompasses a range of activities that is more than assimilation of information, but can involve achieving new understanding or developing a skill by practising. Learning is further discussed in section 1.1.2.

The combination of learning and working activities can help achieve the necessary competencies required for the individual and the organisation. On a daily basis, individuals often shift seamlessly from performing computer-based work tasks to accessing online help or search facilities to gather information on selected topics to complete their tasks. Support, guidance and/ or advice also can be sought from a networked community with similar interests. In the long-term, combining working and learning activities can lead to individuals in industry attending part-time or short courses to renew their skills. Similarly, academics can be involved with industrial consultancy activities as well as their traditional lecturing and research work at the university. Students can have industrial placements for six months or a year included as part of their degree course. The author has experienced all of these blended working and learning situations during her engineering career.

Continuous professional development for engineers combines the development of theoretical knowledge with practical work functions, or as Fink & Holifield (2004) puts this - "*a combination of continuing engineering education along with productive engineering.*" This has been a key motivation for the research, and the areas investigated have been the factors that support and enhance learning in academic and industrial engineering development environments.

1.1 Rationale for the Research

From the evidence of increasing globalisation, technological advances, demographic and lifestyle changes, as well as the resulting emergence of the knowledge-based economy in developed countries, industrial and academic organisations are being forced to consider alternative ways to inform and educate their employees and students. The engineering organisations researched recognised this, and so have planned and begun to adopt accordingly a more flexible, technology-enabled learning approach in their current training, informing and teaching practices. In a knowledge-based economy, skills become outdated at an accelerating rate. One study conducted by Lynch (1999) estimated that "*over 50% of all employees' skills* *become outdated within three to five years of induction"*. Thus, to keep engineers competent and updated with the necessary skills, their training and learning need to become continuous processes rather than one-time activities.

To provide clarity on what an engineer is or does, in the context of this research, the definitions of an engineer and the working and learning engineering environments are described next.

1.1.1 The Engineer & Engineering

In the UK, the term 'engineer' has broad application. Therefore, to ensure that there is no ambiguity throughout this Executive Summary, the author defines the term 'engineer' to refer to either professional or student engineers in development environments:

- **Professional engineers** in this context are those involved with all aspects of 'product-development', working in the Engineering Department of a company. Here, the work activities consist of research, design, prototype build and testing, as well as collaboration with other team members, departments, customers and suppliers.
- **Student engineers** in this context are those studying at university in the School of Engineering on post-graduate masters (MSc) degrees who initially share the responsibility for their own 'self-development' with tutors. Eventually when the post-graduate students leave academia, they need to become fully responsible for their own continuous life-long learning.

Engineering represents a key area of adult education, and though there are various branches of engineering, such as mechanical, civil, chemical, aeronautical and electrical, the fundamental nature of engineering is similar across all disciplines (Kemper & Sanders, 2001). Certain cognitive processes are particularly important in all engineering tasks, such as problem-solving, analytical reasoning and critical thinking. Often engineering involves product innovation or invention, and so exploratory discovery skills are necessary. Tenopir & King (2004) describe an important characteristic of the iterative product-development process as 'finding' as well as 'solving' problems. This is similar to Schon's (1983) comments about reflection on problems, with the ability to 'problem-set' as well as 'problem-solve'. Additionally, Schon explains that through a feedback loop of experience, learning and practice, an individual can continually improve his or her work (academic or not) and become a 'reflective practitioner' (Schon, 1983). The work of Schon fits in with Deming's (1993) continuous improvement cycle of plan, do, study, act (PDSA) and aspects of Kolb's (1984) model of experiential learning. Kolb, a professor in organisational behaviour, provides one of the most useful, and cited, models of the adult learning process, and his work is referenced throughout this document, particularly in sections 4.1.1.2 and 4.1.3.

Engineering has undergone considerable transformation over the last decade, with electronic business (e-business) technologies and the concept of the extended global organisation increasingly being implemented. Non-core activities are frequently outsourced to external organisations, which then become part of the supply chain, consisting not only of component suppliers but service suppliers. They form an integrated, global, co-operative network to provide manufactured goods and support services to the world market (Thoben & Schwesig, 2002).

Professional engineers provide the engineering competences in such extended global organisations. Therefore, they are required to have the necessary technical knowledge of processes and technologies for effective working as well as understand and communicate with different engineering and manufacturing systems. Modern engineering activities are increasingly becoming more collaborative and multi-disciplined, as engineers work with dispersed colleagues and suppliers, and adapt accordingly to different situations as they arise (Tenopir & King, 2004; Kemper & Sanders, 2001). In addition to being competent in engineering fundamentals, Denning (1992) states that engineers must be prepared for continuous lifelong learning to remain current in their field, and be skilled listeners for dealing with suppliers and customers, as well as rigorous in management functions.

Therefore, courses for engineering students need to be constantly extended and updated with relevant knowledge (Hoheisel et al, 2001). However, Thoben & Schwesig (2002) among other educationalists believe that the present education system has not been able to completely reflect the 'real' needs of industry, as modern engineering functions increasingly require:

- Global multi-cultural environments.
- Multi-disciplined, multi-skilled teams.
- Shared activities globally, 24 hours a day.
- Electronic tools for communication and collaboration.
- Virtual development environments.

Hence, the above requirements need to be considered when developing content for engineering students, not only to provide experience with the enabling tools and technologies for addressing these modern engineering functions, but also to provide an understanding of the affects these will have on them as professional engineers. For example, workplace trends place greater demands on professional engineers, but provide them with little or no extra time to adapt to changes. Consequently, this often extends the number of working hours, resulting in less time available to keep updated with new information and to learn (Pearn et al, 1995; Landen, 1997; Pedler et al, 1997). Globalisation increases business travel needs for individuals, which further reduces the time available for keeping informed, trained or educated, and so continuous professional development can be limiting for today's working engineers (Fink & Holifield, 2004). Web-based communication technologies, such as video conferencing can help to reduce business travel, although not eliminate it completely.

Companies can also be reluctant to provide continuous professional development or training courses to all but their core staff. There is a tendency for larger companies to retain a core set of employees and employ contractors on a short-term basis to smooth out resource demand. From the author's own experiences, observations and research, an engineer performing the same job function or even remaining with one organisation for his or her entire career is increasingly unusual. The engineer's mobility can be between teams, departments, sister companies, suppliers, customers or competitors. Many contracting engineers establish themselves as either self-employed sole traders after several years of experience, or as consultants if they have a specialised skill, such as being proficient with finite element analysis (FEA) software, or specialised knowledge, such as in press-tool design. If modern engineers are to meet the requirements of global engineering organisations, they need to take some, if not all of the responsibility for their own learning and keep up-to-date with their engineering knowledge and skills. In order to facilitate this, it is important for learning providers to develop flexible learning environments to encourage and maintain individuals to continuously learn, where and when necessary, and to satisfy the various learning requirements for engineers.

1.1.2 E-learning Introduction

Electronic-learning (e-learning) presents a solution to address the engineering requirements by providing a learning environment that can be self-directed and also guided, individual and also collaborative, global and also local, and standard and also customised. Further investigations into e-learning revealed the opportunity for universities and business-to-consumer (B2C) training providers to develop and deliver their own learning content to individuals at their place of study, work or home, at anytime. E-learning covers a wide range of applications and processes (Urdan & Weggen; 2000), which can enhance and support information-bases, knowledge-bases and skills-bases for individuals and organisations. The author also identifies e-learning to encompass any electronic technology that is used to assist or increase understanding. For example, using a computer-aided design (CAD) system to become competent at engineering design and development, or using a Web search engine to retrieve information and then apply it in context to a task. The author brings together the main descriptions of e-learning encountered in the literature to encompass learning or training that is prepared, enabled, delivered, supported, managed and/ or enhanced using a variety of electronic technologies. The Oxford Dictionary (Hornsby, 1974) defines learning as *"to gain knowledge of or skill in, by study, practice or being taught"*, and defines training as *"to give teaching and practice to, in order to bring about a desired standard of behaviour, efficiency or physical condition"*. In the initial stages of training or teaching, the learning instruction is presented and demonstrated to the students. This is similar to 'learning as acquisition' for the 'push' of information, which tends to follow the objectivism learning theory, as learners are given the information controlled by the instructor. Whereas 'learning as participation' for the 'pull' of information follows the constructivism theory, as learners interpret information and learning evolves under their control. Both the objectivism and constructivism learning theories are important for the engineer's development and are discussed further in section 4.1.1.3.

The research predominantly refers to learning (and e-learning), as the outcome from training or teaching (electronic-enabled or not) is that the individual normally learns something. However, Jarvis (1995) states that *"learning may, and often does, occur without teaching, but the extent to which teaching can occur without learners and learning is much more debatable"*. Therefore, a more appropriate description is that training or teaching has the intention to bring about learning rather than stating learning explicitly occurs as a consequence of training or teaching.

Kolb (1984) provides a more embracing definition of learning as being *"the process whereby knowledge is created through the transformation of experience"*. This identifies the learning process from an experiential viewpoint by emphasising knowledge as a transformation process which is continually created, adapted and re-created. This definition relates to 'learning by doing' and the continuous improvement processes required for work-based engineers and engineering students. In undertaking the research, the author learnt experientially and this underpins the action research methodology adopted. The involvement with e-learning applications and their development helped to provide experience and understanding of the practical capabilities of e-learning and its relationship with individuals and engineering organisations.

The effects of deploying e-learning solutions have been well documented in much of the e-learning literature reviewed (Khan 2001; Urdan & Weggen; 2000; Harris & Shepherd, 1999; Steed, 1999; French et al, 1999; Hall, 1997), and these were reinforced by the e-learning applications case studied. The main effects of e-learning that were identified by the research are as follows:

1) **Cost-effective learning:** After the initial development set-up costs, e-learning can provide inexpensive local, i.e. organisation-based, as well as global distribution of content delivered via networked computers to a large number of individuals. Also, there are no expenses incurred for an individual's travel, subsistence or accommodation as with off-site instructor-led courses. E-learning activities and lessons can be delivered and re-used again and, as Urdan & Weggen (2000) point out, can incur less re-development costs than with traditional training methods. However, if an area of the learning content is not reusable due to its high speciality, complexity or short life-span, then e-learning in that area may not be a cost-effective solution.

2) **Efficient learning time:** There can be minimal work time lost when requesting the required content to learn just-in-time (JIT). This is because after JIT, also referred to as on-demand or 'immediate' learning and training, individuals can directly apply what they have just learnt to the required task or problem. If individuals are allowed to learn at their own convenience and are self-directed, they are able to manage their

own learning time as well as the pace and amount of learning. However, there can be technology problems with e-learning that frustrate learners and cause inefficient learning time. For example, Steed (1999) identifies that with bandwidth limitation problems, i.e. the data communication transmission rate, learners can experience long waiting and response times as well as slow media performance.

3) **Improved self-development & management:** The self-managed learner can be a useful resource to the organisation, given the right training and guidance (Pedler et al, 1997). Nevertheless, an organisation still needs to keep their employees informed of any changes in its business strategy, so that they can seek and request appropriate training for any competencies required. Empowered individuals can often arrange their own training and learning activities to fit around their workplace tasks, and this was illustrated in the industrial case studies. The investigations identified that in academia and industry senior management need to continually support and encourage learning throughout the organisation. Obtaining management support & commitment for an e-learning development is an important critical success factor (CSF) from a business perspective, and this is discussed further in point (1) of section 5.1.

4) **Customisation of content to suit requirements:** E-learning courses can be customised to meet specific training or learning needs for an organisation, a department, a product-development team or an individual. Yet, initial development resources, such as time and people, can be considerable for authoring customised content and integrating its delivery, compared to an 'off-the-shelf' solution. Ismail (2002) comments that even if part of an e-learning development is out-sourced, a dedicated in-house team still needs to supervise and manage this as well as its deployment. Also, a rigorous selection and evaluation of the potential external e-learning providers that supply development services needs to be conducted. Point (5)

in section 5.1 discusses this aspect further within the Warwick Manufacturing Group (WMG) case study, where WMG is part of the School of Engineering at the University of Warwick.

5) **Knowledge exchange and sharing:** An e-learning environment can facilitate an openness to share new information, knowledge and skills with other peers (French et al, 1999; Dixon, 1998). Yet, this depends on individuals' characteristics, their willingness to share, and the type of learning environment. If information has a value to individuals they may not be comfortable with sharing this, especially if they are to be assessed on the content, such as with a post module assignment (PMA) after attending a MSc module at WMG. The industrial case studies identified that core team members more readily share information and their experiences with peers, as they often have a common goal such as the joint responsibility in a product's development. The author has experienced this when giving assistance to a fellow engineer at work, whether to explain a design calculation, lessons learnt, or to demonstrate a piece of CAD functionality, the engineer knows that the favour will normally be returned. This trust-based sharing of experiences can be considered as a favour exchange of knowledge. Steed (1999) remarks that the comprehension and confidence of individuals increases by sharing information with peers. In industry this can be between other team members, departments, sister-sites, suppliers and customers. However, organisations have a vast amount of knowledge, information and lessons learnt in a wide variety of processes, procedures, company standards, databases and, as Gupta et al (2000) point out, in individuals' heads. Therefore, this diverse and diffused knowledge needs to be made available, and properly shared and managed. If it is able to be written down and recorded in some way, then the information can be organised and computerised where appropriate, and be accessible to novice users throughout the organisation. However, the author appreciates that not all knowledge can be written down easily and so an interactive virtual learning

environment (VLE) may be required to present demonstrations. This can also encompass adopting virtual reality (VR) and simulation techniques, or online streamed video demonstrations.

6) **Access to current and consistent learning content and revisions:** After the original implementation of an e-learning lesson or a complete programme, further lesson changes, additions, enhancements or developments can be made with little effort. The content, residing on a server, is updated once and everyone in the organisation, even globally if authorised, can access the latest version of the e-learning activity, lesson or programme. This functionality makes e-learning an efficient learning solution. The immediate distribution of the latest information, allows an organisation to adapt quicker to its operating environment, due to better-informed employees (Rosenfeld & Wilson, 1999).

7) **Accepting changes in learning methods:** Individuals need support as well as time to adapt to new methods of learning. This was observed at WMG during the pilot runs of the e-learning activities, as decreasing instructor-led contact made some students anxious. To overcome this, e-learning needs to be gradually introduced into an organisation. Also, all individuals being affected, i.e. the stakeholders, need to be involved at the start of an e-learning development, so that they are more likely to accept any changes made (Steed, 1999; French et al, 1999).

8) **Utilisation of existing resources:** Existing technical infrastructures and networked computers in organisations can be utilised to run e-learning activities. The Web browser provides the interface to the Internet or Intranet for accessing the e-learning environment on any platform such as Windows, UNIX, LINUX, Mac or OS/2. An interoperable e-learning solution is able to be delivered to any networked computer without authoring a different solution for each platform. This was an important aspect for the WMG case study, because students away from the classroom often had

their own computers on various platforms, and it would be impractical and time consuming if Instructional Developers provided different solutions for each student.

9) **Interactive and engaging learning environment:** E-learning can facilitate a rich interactive environment for both individual and collaborative learning by using appropriate multimedia to suit the environment. This can be made more engaging by customising the environment by providing appropriate learner-specific content and accounting for preferred learning styles. Yet, care needs to be taken not to overexert the multimedia aspect as this can distract the learners from the necessary learning (Spool et al, 1999). The speed of interactive responses can be slow if there are large multimedia files to download or refresh, and this can also frustrate the learner. Gaining and maintaining learner's attention is described in section 4.1.2.

10) **Concurrent assessment tools:** E-learning content can incorporate online assessments and tests for instructors to monitor the students' progress. Self-directed learners can also record and track their own work as well as test their knowledge. From this, future content can be customised to suit the capability and progress of the learners. Learner assessments are further discussed in section 4.3.5.

1.1.3 Research Question

In theory, e-learning can lead to providing an 'effective' learning environment for professional and student engineers, in order to meet the demands of the changing workplace and study place respectively, as well as accommodate changing lifestyles. The author has used the word 'effective' when describing learning in this context, as it has many desirable attributes, such as - flexible, accessible, beneficial, customisable, efficient, enhanced, as well as improved. E-learning not only assists in effectively fulfilling an engineer's product-development tasks and self-development needs, but subsequently can lead to effective collective organisational learning. Mason (2002) states that, *"it is not the electronic nature of e-learning which captures its true* *value, but rather the opportunity to integrate working, learning and community"*. This lifestyle integration has been a key consideration for the author when reviewing the literature and planning the case studies, and thus has been emphasised throughout the author's submissions. Consequently, the main research question addressed has been...

"How can e-learning provide effective learning for engineers in development environments?"

This question puts the emphasis on 'how' because the research needed to investigate the various ways e-learning contributes to providing improved learning activities for engineers, beyond providing just the technological capabilities. This need raised further sub-questions. The next section identifies the main research objective and the underlying sub-questions.

1.2 Research Objective & Associated Questions

The research revealed gaps both in the existing literature and working practices, regarding the e-learning needs of engineers and in current approaches to provide an holistic e-learning solution that can integrate different factors to meet these needs. Consequently, the main objective of the research was to develop a mechanism to assist learning providers combine different factors to produce effective e-learning activities in engineering development environments. A framework was developed for this mechanism because it was found to be more flexible than a methodology or model, as it enables disparate learning factors to be grouped together and sequenced differently depending on the learning requirements. A more detailed discussion on the rationale for adopting a framework is presented in section 3.1. However, to help understand and achieve the main objective, further sub-questions needed to be raised and answered:

Q1) **What is the existing status of learning in engineering development environments within industry?** Addressing this question provided an understanding of present training and learning methods that are available in Engineering Departments within industry. This provided the starting point for the research. Consequently, this helped to identify areas where e-learning is able to replace or complement existing learning methods in engineering environments. An important aspect of this was to establish if present training and learning methods were aligned to engineers' preferred style(s) of learning.

Q2) **Do professional engineers, predominantly in design and development, learn differently from other professionals and more senior engineers?** Answering this question helped to determine engineers' learning style preferences, in order to match appropriate technologies to these preferences. A key finding was that engineers have a strong visual learning style preference and section 4.1.3 discusses this further. Catering for engineers' learning preferences at the start of developing e-learning content can help to provide customised activities and make their learning environment more engaging. After establishing the learning preferences, different tools and techniques to facilitate these preferences were researched.

Q3) **What technologies are available to provide more effective ways of learning?** This question followed on from question (Q2), as the current capabilities of available technologies, especially those influencing e-learning such as Web-based tools and techniques needed to be understood. The author determined and grouped the different enabling technologies for delivering, supporting and enhancing learning activities, with the focus on engineering environments. Following on from this, what Web-based learning providers actually offered was investigated.

Q4) **What products, services and technologies do Web-based learning providers offer?** This question focused on what Web-based learning (WBL) providers currently supply, from the enabling Web technologies to bespoke e-learning lessons. This identified a fragmented marketplace of the WBL products, services and technologies available. WBL is a sub-set of e-learning (Steed, 1999; Ravet & Layte, 1997). Understanding the e-learning providers' perspective helped the author to appreciate the e-learning marketing considerations, such as external environmental forces and the different e-learning audience. Next, the research then brought this and the former questions (Q1), (Q2) and (Q3) together to group and connect the main learning factors investigated.

Q5) **What are the main e-learning development issues to consider and how can different learning factors be related?** Addressing these questions helped to propose an e-learning framework that identifies and categorises the important factors affecting e-learning development. Synthesising such a framework addresses the key research question by providing a mechanism to guide e-learning providers produce effective e-learning content for engineers. Also, identifying the different e-learning stakeholders helped to recognise their various roles and responsibilities, as well as the different relationships they have with each other and with the framework. CSFs were produced to provide a business perspective to incorporate organisational issues into an e-learning plan of action. The framework and CSFs were developed as a consequence of the research. The different engineering environments helped to test, verify and refine the factors in the framework, and the CSFs were applied to the WMG case study. These are explained in chapters 4.0 and 5.0 respectively.

Q6) **How do these learning factors compare in academic and industrial engineering organisations?** This investigation helped to understand, review and refine the e-learning framework from different academic and industrial considerations in current engineering learning practices. For example, academia may teach engineering students 'general' database knowledge, whilst industry may specialise to train 'specific' Oracle database skills. However, the research showed that there is a necessity to combine both types of learning in engineering. This is discussed further in section 3.3 and the case studies are drawn on to verify this. Section 3.4 presents guidelines for utilising the framework to select and order appropriate learning factors within the framework's categories.

The following section 1.3 introduces the main project work undertaken to address these sub-questions (Q1) to (Q6) and the issues they raised, and these been reported in the respective Engineering Doctorate (EngD) submissions. How these sub-projects have contributed to the scope and structure of the research are also explained.

1.3 Research Scope & Structure

This Executive Summary presents an overview of the research conducted during a four-year period and draws upon five main projects written up as submissions, each being in partial fulfilment for the EngD. This section explains the systematic actions undertaken to accomplish these projects and addresses the sub-questions raised in the previous section 1.2. The project findings are introduced where appropriate, particularly if they have influenced succeeding projects. These projects contribute to the scope of the research, which has led to the development of the novel e-learning framework presented and discussed in this document. The respective EngD submissions and the structure of the Executive Summary are outlined next:

- **Submission 1 - The Relevance of Technology-based Learning in Engineering Design (James-Gordon, 2001):** The investigations for this submission identified areas that addressed questions (Q1) and (Q2) of section 1.2, to help establish why technology-based learning (TBL) is important for engineering development environments. The areas of study were as follows:
    - Current training and learning methods in Engineering Departments were investigated, in order to gain an understanding of current training and learning practices, and thus answer question (Q1) in section 1.2. Two different, but representative, engineering environments in automotive companies provided the case studies for this investigation. Their current practices were found to combine standard and customised, in-house and off-site instructor-led training

with self-directed learning. The author wanted to establish to what extent individuals were responsible for choosing their own methods and direction of learning, and so self-directed learning was of particular interest to this research. The industrial case studies did support self-directed learning, as after attending instructor-led training courses, engineers were encouraged to use their newly acquired skills straight away and 'learn on the job'. When uncertainties arose, they applied other self-directed learning methods such as referencing manuals, collaborating with peers and utilising online help facilities. Self-directed learning in the academia case study was mainly experienced in student assignments and project work. Section 4.1 describes self-directed learning further within different aspects of the philosophy category of the framework. Section 3.3 discusses the different training and learning practices experienced.

- Next, two surveys were conducted to identify engineers' preferred learning styles, to ascertain if these were aligned to the current learning methods and technologies, and thus answer question (Q2) in section 1.2. Two established questionnaires were used for this, one based on Honey & Mumford's work (1992) and the other on Felder's work (1996). The reasons for selecting these questionnaires are discussed in section 2.2.3. The first survey found that there was an even distribution of engineers and senior engineers, against the activist, reflector, theorist and pragmatist learning styles tested. This finding was not unexpected, as engineers in industry adopt different learning styles, depending on where they are in their exploratory process or product-development cycle, in order to optimise a solution. The main findings from Felder's questionnaire found that engineers, including more senior engineers, have a strong visual learning preference compared to the rest of the professional population. Thus, visual techniques are particularly important when developing learning activities for engineers. The CAD training that was observed and practised in the case studies did incorporate visual functionality. For example, CAD presentations and demonstrations were linked to the CAD workstations; graphical icons were used to select commands; and the CAD parts were sketched, designed, assembled and analysed using coloured graphics. Learning styles are further discussed in section 4.1.3. Appendix A1 presents a paper titled 'Learning Style Preferences of Engineers in Automotive Design', where the analysis and findings from the questionnaires were published.

- After determining learning methods and styles of engineers, the effects of utilising technology to support learning in an organisation were investigated. The initial investigations presented TBL as a possible solution to incorporate a self-directed and customisable environment to accommodate engineer's learning style preferences. TBL was also shown to provide a collaborative and distributed learning environment for engineers. Section 1.1.2 discussed these aspects within the introduction of e-learning, where e-learning is shown to be a sub-set of TBL. The next submission provided detailed investigations into the TBL tools and techniques.

- **Submission 2 - Technology-based Learning Tools & Techniques (James-Gordon, 2002a):** This submission investigated what TBL tools and techniques were available to provide a part or complete solution for enabling a more effective way of learning for engineers. The current technologies studied provided the support or enhancement to the learning environment, and accommodated the learning style preferences. This was considered as the main literature review to the research, and addressed question (Q3) of section 1.2. The reason why this study was done after the first submission was because current practices first needed to be established before investigating how improvements can be made by the different factors that affect learning. The areas of study were as follows:

- Physical supporting technologies were researched and classified as 'hard' learning technologies to distinguish these from softer technologies explained in the next point. The 'hard' technologies encompass Web-based technologies, which have been of particular interest in this research due to their wide reach and interactive impact on the modern working and learning environments. Various e-learning software products were also identified and classified depending on their capabilities and limitations. The research established that e-learning products had predominantly been developed for Web-based academic distance learning courses, but Urdan & Weggen (2000) comment there is an increasing need to develop effective company-oriented e-learning environments. The fast evolution of many of these products made classifying them according to their main purpose difficult. Therefore, different e-learning products were selected and examined from many sources (Khan 2001; Urdan & Weggen; 2000; Harris & Shepherd, 1999; Steed, 1999; Young et al, 1999; Ravet & Layet, 1997; Hall, 1997), based on their commercial popularity or current availability at WMG. These products were categorised from basic authoring tools to more sophisticated learning management systems (LMS). The main collated comparisons are shown in table 4-1 of section 4.4. This second submission provided an understanding of the functionality and flexibility of these products, and to what extent they can develop, deliver and/ or manage the learning content and activities, and integrate with other products. Therefore, this addressed question (Q3) in section 1.2.

- The research also examined non-tangible enhancing 'soft' learning technologies to illustrate the different facets of technology in the learning environment. The 'soft' technologies encompass instructional principles, which influence the philosophical side of learning, and are described further in section 4.1. Yet, other 'soft' learning technologies examined were found to be more controversial, such as subliminal learning influences, and smart drugs and nutrients. However, the author wanted to investigate these in order to provide a balanced approach to studying all technological aspects of the project. Consequently, the author felt that the scope of TBL was too broad, as the technologies researched ranged from the physical computer-based tools to the more controversial biological technologies such as smart drugs. Therefore 'e-learning' narrowed this area down to electronic technologies investigated. In this research, e-learning encompasses WBL as well as stand-alone computer-based learning (CBL) (Steed, 1999; Ravet & Layte, 1997). To further understand the e-learning market, the next submission divided the WBL products offered by the providers into WBL content and service, as well as technology.

- **Submission 3 - Marketing Considerations for Web-based Learning Providers (James-Gordon, 2002b):** This submission explored marketing considerations for WBL providers supplying content, technology and services to academic or industrial organisations. These organisations then provided their tailored WBL solutions to their students, employees or other organisations. WMG was viewed as an education provider for engineering students. This submission addressed question (Q4) of section 1.2, by establishing how and what these providers offered. Determining marketing considerations from the WBL providers' perspective gave the author an appreciation of what can be achieved within the environmental constraints and the fragmented e-learning market. Appendix A4 presents a paper titled 'External Environmental Forces Affecting E-learning Providers', where the findings of the marketing considerations were published. This third submission also introduced the author to the business side of e-learning, which subsequently helped with devising the e-learning CSFs for the fourth submission. The first three submissions provided the analysis part of the research as illustrated in figure 1-1, and the core understanding of e-learning. The research then consolidated this understanding gained to develop an e-learning framework, and the work was reported in next submission.

- **Submission 4 - Proposed Framework for Designing E-learning Content (in an Engineering Environment) (James-Gordon, 2003):** This submission addressed question (Q5) of section 1.2 by reviewing, developing and integrating various issues from the first three submissions. The consolidation of this previous work and findings, together with additional research assisted in developing the e-learning framework. Chapter 3.0 discusses why, when and how the framework is adopted to assist e-learning providers develop e-learning activities. Chapter 4.0 describes and reviews the main learning factors that have contributed to its composition, and draws upon examples in the case studies. The framework groups learning factors into philosophy, delivery, technology or management categories depending on their function. The factors in these categories are not necessarily comparable with each other, employed altogether or applied in the same sequence for e-learning applications. Section 3.4 provides the guidelines for using the e-learning framework and shows the integration with the framework categories. The fourth submission additionally investigated CSFs associated with change relating to an e-learning implementation, and dealt with organisational and human factors, as well as technological issues. The CSFs provided a business viewpoint for developing an e-learning environment which complements the e-learning framework. Following this, the author verified areas of the developed framework in different engineering situations, which led to the work for the next submission.

- **Submission 5 - Applications of Engineering E-learning Environments (James-Gordon, 2004a):** This submission examined e-learning operations in different engineering development environments, as well as compared their learning requirements and effects, and so addressed question (Q6) in section 1.2. This helped verify and reinforce areas of the e-learning framework developed from the fourth submission, and was achieved by using three different engineering case studies: two industrial and one academic. These case studies were not intended to be conclusive, but illustrated the diversity of engineering e-learning environments. The areas of study were as follows:

- The industrial case study work were with Cisco Systems and Company X. (Company X is an automotive company wishing to remain anonymous for the purpose of this research which is explained in section 2.2.2.) WMG provided the academic case study. Cisco Systems provided the benchmark for the other case studies, as this organisation was one of the pioneers of integrating e-learning into their workplace (Lee, 2003). Company X was chosen as the second industrial organisation because of its need to advance from a basic information-base, despite having adopted other modern working practices. WMG was selected because it was at the start of introducing e-learning activities into one of its post-graduate MSc programmes. Table B-1 in appendix B compares the different learning factors against the engineering applications of the case studies. Reasons for selecting these organisations are further explained in section 2.2.2 together with profiles of these organisations.
- Next the author applied the CSFs, established from the research and written up in the fourth submission, to WMG's e-learning environment. Chapter 5.0 discusses and exemplifies each CSF. WMG was case studied because Cisco Systems' e-learning environment was already developed and Company X had yet to obtain full management support to further its e-learning environment. Comparisons made between the academic and industrial engineering applications have helped to validate and refine the framework.

- **Executive Summary – An E-learning Framework for Engineering Development Environments:** This report summarises and reflects on the research, and brings together the main aspects from all the projects undertaken by the author over the four years of the EngD Programme. The structure of this Executive Summary is as follows:

- **Chapter 1.0** explains the rationale for the research. This identifies the need to integrate learning and working activities to meet the demands of the workplace and keep engineers competent. E-learning is introduced as a possible solution to provide a more flexible learning environment for both professional engineers and student engineers. Explanations of the main research question and associated sub-questions, research objective, research scope incorporating the projects, and key findings are respectively provided in this chapter.
- **Chapter 2.0** describes the complete research methodology under individual methodology sections which identifies the different project approaches undertaken. Justification for using a predominantly qualitative approach is provided for searching, collecting and analysing data for this research. The case studies not only illustrated the diverse engineering environments but they helped to provide more detailed surveys and investigations to be carried out.
- **Chapter 3.0** discusses the context in which the e-learning framework can operate with emphasis on why, when and how to utilise it. The overall framework guidelines are provided which identify the sequences through its structure which address how the framework can be used.
- **Chapter 4.0** describes the development of the e-learning framework, which contains the framework's philosophy, delivery, management and technology categories and the learning factors housed within these. This provides the framework's scope. The main learning factors were identified through a combination of primary and secondary data collections, information researched and reviewed, and the author's knowledge of engineering. Detailed accounts of physical 'hard' and the more controversial 'soft' technologies investigated,

such as 'smart' drugs and subliminal learning influences are not presented in this document, as they are beyond the scope of the e-learning framework.

- **Chapter 5.0** discusses CSFs that have been devised to provide a business viewpoint for an e-learning programme. These CSFs relate to certain learning factors in the framework as well as additional organisational issues.
- **Chapter 6.0** describes the main research innovation and contributing areas of knowledge. The creation of the e-learning framework is identified as the main innovation.
- **Chapter 7.0** concludes the research and sums up the key areas of study. Recommendations for further related work are also suggested in this chapter.
- **Appendix A** provides a copy of each of the author's published papers, as this is a requirement for the EngD Executive Summary. Four of these papers were in refereed journals and two were presented at the World Conference of Educational Multimedia, Hypermedia & Telecommunications (ED-MEDIA). These papers provide supporting data for this Executive Summary and have been referenced where needed.
- **Appendix B** provides two examples of academic lessons, which illustrates how the e-learning framework can be utilised. Table B-1 presents a selection of learning factors from the e-learning framework. These factors were considered for different engineering e-learning environments that were case studied. The complete framework figure and path flow through the framework are also presented here to provide stand-alone guidelines for referring to.

Throughout this Executive Summary, references have been made to the EngD submissions, and so for simplicity, the submission number has been used to represent its corresponding title and entry date into the EngD portfolio. For example, 'submission 1' has been written to represent the first submission, titled 'The Relevance of Technology-based Learning in Engineering Design', submitted into the author's portfolio in 2001.

Figure 1-1 illustrates how these submissions contribute to the research's structure, its sequence order, and the overall scope of the research. The suggested reading order for these submissions is essentially the sequence in which they have been entered into the author's EngD portfolio, as shown in figure 1-1. This figure also includes the sub-question numbers of section 1.2 in red, in order to show which submission they have been addressed in. Submissions 1, 2 and 3 provided the analysis stage to the research, and assisted in tackling questions (Q1) to (Q4). These first three submissions have provided the main background investigations to help understand and address question (Q5). Hence, these submissions are independent of each other and can be read in isolation. Submission 4 combined the former investigations and findings to develop the e-learning framework for use in engineering development environments, and so submission 4 needs to be read after the three previous submissions. Submission 5 then applied and built on areas from submission 4, by comparing and evaluating the proposed framework within engineering applications, and so addressed question (Q6). Thus submission 5 needs to be read after submission 4. References have been made between the submissions to exemplify and reinforce the work in developing the e-learning framework. Finally, this Executive Summary consolidates and discusses the main research areas from all the projects undertaken. This process has essentially followed the analysis, design, develop, implement, evaluate (ADDIE) model (Harris & Shepherd, 1999) for an actual instructional development process. The ADDIE model has been used here to illustrate the function and relationship between the submissions and their inter-dependencies, as shown in figure 1-1. The next chapter discusses the research methodology, which identifies and groups together the various work undertaken within the projects under the respective methodologies.

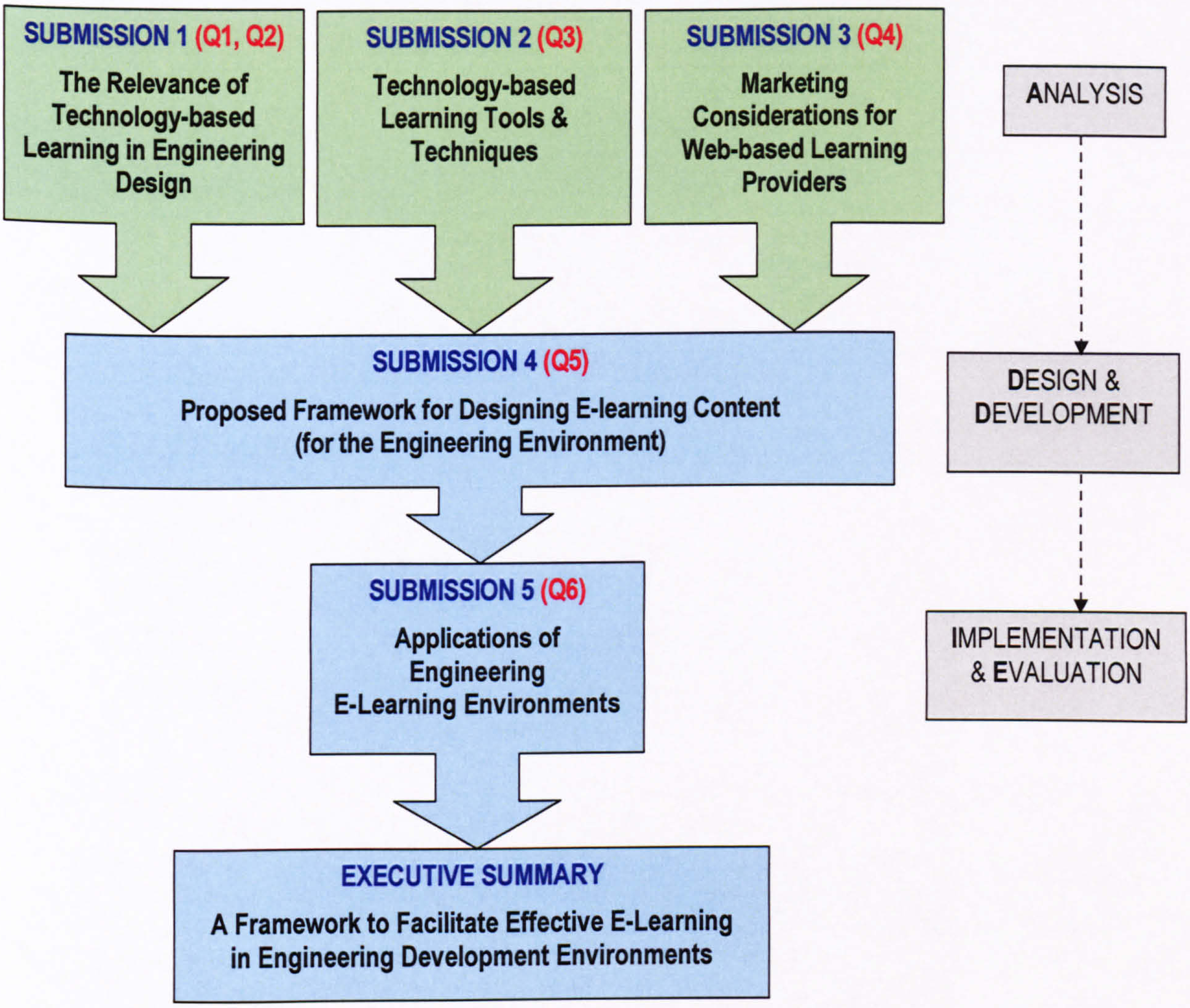


Figure 1-1: Research Scope, Structure & Submission Order

2.0 RESEARCH METHODOLOGY

2.1 Rationale for the Research Methodology

The objective of the research and the associated questions identified in section 1.2 drove the way in which the research was conducted. This provided the research methodology, which shaped the approach the author took through the research activities and project work to address the questions raised. A predominantly qualitative approach to the research methodology was undertaken. The author was an integral part of the data gathering and analysis process as well as an advisory part of the subsequent development and implementation of e-learning activities. Hussey & Hussey (1997) use the term 'phenomenological' to describe the qualitative research philosophy, which is concerned with understanding human behaviour and encompasses the author's own perspective. Also, Van Maanen (1983) points out that research methods under the qualitative approach consist of interpretative techniques to describe, translate, and deal with the meaning.

Although a more qualitative approach was employed for the research, quantitative methods were also incorporated in analysing the results of the questionnaire surveys. Hussey & Hussey (1997) use the term 'positivistic' to describe the quantitative research philosophy, which is related to measurement and seeks to understand of cause and effect. The quantitative research philosophy is at the opposite end of a continuum to the qualitative research philosophy, but the author discovered considerable blurring between the two, where a positivistic approach can produce qualitative data and visa versa. For example, the qualitative questionnaires from submission 1, which established engineers' preferred learning styles, used quantifiable statistical tests to analyse the answers collected. This was then accompanied by in-depth interviews to provide qualitative understanding of the questionnaire surveys. Therefore, combining qualitative and quantitative methodologies has been beneficial to strengthen this research.

Figure 2-1 illustrates the qualitative and quantitative approaches employed in the research. The respective project submission number is shown in red in brackets against the main research methodology employed. (The methodologies adopted are presented also on table 2-1 overleaf, but in submission date order). The sub-sections within section 2.2 describe each methodology fully, and examples are given to illustrate where particular methodologies have been implemented in the various projects. Consequently, these project methodologies have contributed to the complete research methodology of the EngD. Each separate project methodology also has been described fully in its respective submission. Section 1.3 identified the scope for each project and introduced what was achieved. The next section collates the projects in the respective methodology and discusses the complete research methodology.

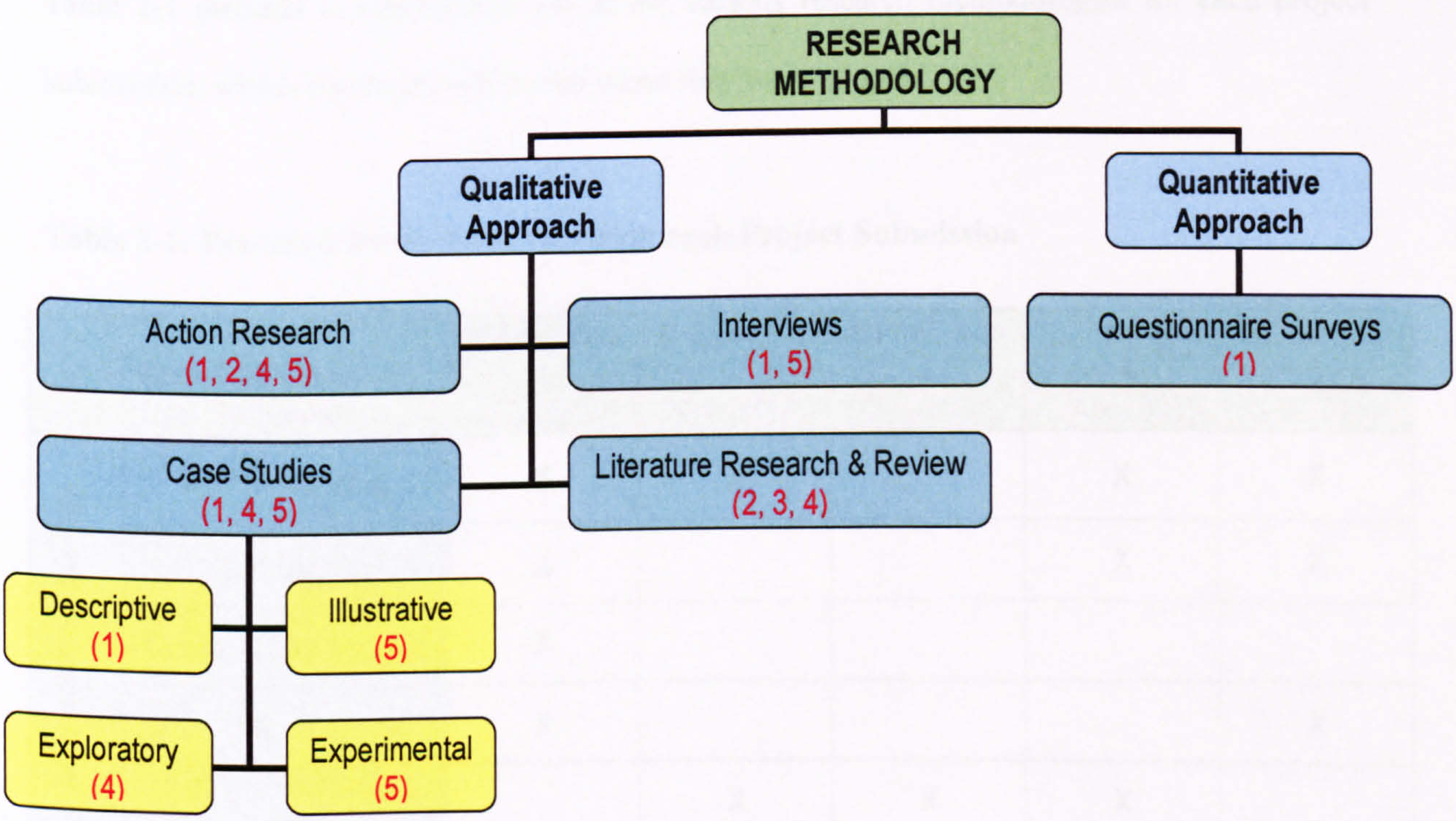


Figure 2-1: Qualitative & Quantitative Approaches in the Research Methodology

2.2 Research Methodology for the Projects

The predominantly qualitative approach adopted for this research took the form of action research, case studies and interviews. This was because of the subjective nature of the research which focused on understanding the various factors of e-learning and how these factors were applied. Nevertheless, a quantitative approach was utilised in the questionnaire surveys, in order to identify current learning methods and learning style preferences in engineering, and this is further discussed in section 2.2.3. Interviews and discussions with key stakeholders were important to evaluate more subjective issues and emotional attitudes, such as those raised with the questionnaire surveys. Interviews are discussed further in section 2.2.4. Throughout the EngD research, the author constantly reviewed the literature in order to keep abreast of any advances in e-learning, especially with the enabling technologies and the emerging e-learning providers. The literature research and review is discussed in section 2.2.5. Combining various research methodologies helped to provide the author with an understanding of e-learning from different angles, as well as strengthen or clarify learning issues from different stakeholders. Table 2-1 presents a summarised list of the various research methodologies for each project submission, which illustrates where and when they were adopted.

Table 2-1: Research Methodologies within each Project Submission

Project Submission (Date Submitted)		**Submission 1** (Jan 2001)	**Submission 2** (Feb 2002)	**Submission 3** (Jun 2002)	**Submission 4** (Apr 2003)	**Submission 5** (Jul 2004)
Research Methodology	Action Research	X	X		X	X
	Case Studies	X			X	X
	Questionnaire Surveys	X				
	Interviews	X				X
	Literature Research & Review		X	X	X	

KEY: X = Research Methodology adopted

The next sub-section begins with discussing 'action research', which has been the primary research methodology implemented throughout this research and employed in the projects.

2.2.1 Action Research

The main methodology adopted has been based on the 'action research' approach, which assumes that the social world is changing, and the author and research are part of this change. This was demonstrated by the author's involvement with engineering environments and their e-learning practices, decisions, developments and implementations in varying degrees. Lewin (1951) coined the term 'action research' as he perceived the process of enquiry as forming a cycle of planning, acting, observing and reflecting. This process can be compared to Kolb's experimental learning cycle (1984), which has been referred to many times in the research and is discussed in section 4.1.3. The author experienced these comparable cycles and adopted their different styles at different stages of each project.

Participating in 'real' engineering applications and maintaining industrial links has been necessary for the author to continually observe, record, consider, analyse, develop, apply, test, evaluate, verify and refine the issues in the evolving e-learning framework. For example, regular contact with industry allowed the author to develop, apply and refine the sequence of the learning modes activities during the delivery of the author's CAD training. Learning modes are important to the learning process, as individuals progress through presentation, demonstration, guided and self-directed activities to problem-solving exercises as they gain experience, and this is discussed further in section 4.2.1. The main research work was consolidated and written up in submission 4 with emphasis on the engineering development environment. Then, submission 5 applied, verified and refined various e-learning issues from the industrial and academic case studies, and where appropriate, recommendations and designs were made for the e-learning environments investigated. This helped to reinforce and refine areas of the framework. The case studies formed a major part of the action research methodology. They provided timely snap-shots of e-learning situations within the environments studied, which were part of the continuous action research. The involvement with the e-learning applications ceased in September 2004, but detail of the case studies work and reasons for using them are discussed next.

2.2.2 Case Studies

Case studies were used to explore parts of the research where there was limited information available, as well as provide a better understanding of current practices. Figure 2-1, at the beginning of this chapter, illustrates the different types of case studies adopted and this section discussed these.

Two different, but representative, automotive engineering companies provided the initial case studies: One is an original equipment manufacturer (OEM), medium sized (>50 employees <250) British company with an organic organisational structure. This company practises modern, i.e. lean, working processes and has a flat management structure. The other is a tier-one supplier, large (>250 employees) international company with a mechanistic organisational structure. This company is a traditional engineering company with a multi-layered bureaucratic management structure. As this Executive Summary will be in the public domain, these two main automotive companies studied have expressed a wish to remain anonymous, and have therefore been referred to as 'Company X' and 'Company Y' respectively throughout this report.

The initial Company X and Company Y case studies were 'descriptive' as they provided in-depth knowledge of existing training and learning practices in two different automotive companies. Company X was then studied further to investigate preferred learning styles of engineers, which is discussed in section 4.1.3. This involved conducting structured interviews, informal discussions, observations and questionnaire surveys to support and provide practical reinforcement for this case study. The author's experiences of the companies provided additional working knowledge of their practices. The people interviewed, observed and surveyed for the case studies consisted of the Human Resource (HR) Managers, Engineering Managers, Training Supervisors, Team Leaders, Project Engineers and Design Engineers in both companies.

The case studies helped to develop the framework and the CSFs. These can be described as 'explanatory' case studies as they provided the understanding and explanation of how engineering applications at different levels of their e-learning development required assistance. Then, the subsequent review of the e-learning framework and further refinement to its development can be described as 'illustrative' case studies, as they demonstrated academic and industrial variations in engineering e-learning environments. The case studies were of Cisco Systems, Company X and WMG.

Cisco Systems provided the benchmark for the other case studies, as this organisation has been one of the pioneers of integrating e-learning into their workplace (Lee, 2003). Additionally, Cisco Systems has combined 'structured' learning activities for their employee's self-development as well as planned work tasks, and 'emergency' learning for immediate workplace tasks. Company X was chosen as the second industrial organisation because the author has worked with their self-directed engineers for over 10 years, and thus has extensive experience of their operational processes and company culture. This provided the author with first-hand working knowledge of the company and, as their engineers and managers knew and trusted the author, they were more willing to offer up information in discussions. Hence, the experience the author has with Company X helped to interpret the research findings better. However, the author was aware that biases and formed views can influence findings, and so to minimise this, structured questionnaires and follow-up interviews were carried out. Consequently, the author shared the research work with Company X's Engineering Department to help design their required engineering e-learning content, as they had only developed a basic information-based system. Hence, an improved portal design for accessing the engineering information and training material is Company X's next e-learning development phase, once full management support is obtained.

The academic application focus was on the post-graduate electronic Engineering Business Management (E2BM) MSc degree within WMG in the School of Engineering at the University of Warwick. WMG has partnerships with industry, as well as providing post-graduate degree programmes. WMG was selected as the academic application as the e-learning lessons were being introduced into their E2BM MSc programme. Hence, the author had the opportunity to work closely with the e-learning development team at WMG to observe, make recommendations, assist and review the WMG's approaches during the years 2000 to 2004.

The 'illustrative' case studies investigated helped describe their newly adopted or proposed e-learning practices of such organisations developing e-learning content. Then WMG provided an 'experimental' case study by implementing e-learning techniques within their E2BM programme that were developed from piloting various learning factors and involving different external providers. The author subsequently developed CSFs because of the problems encountered from these pilots as well as other case studies, in order to provide business guideline for further e-learning implementations.

The three main applications studied were written up in submission 5. The author participated in two of them closely and so obtained primary data. However, when researching the Cisco Systems case study only secondary data was available. Consequently, the case studies have helped examine, test, verify, clarify, refine and reinforce areas in the framework and CSFs, which encompass the various requirements for engineers in academic and industrial development environments. The case studies illustrated the different roles in engineering and even though the case studies were not conclusive, they represented the diversity of the engineering environment.

The research focus has been on engineering development environments because of the continual need for engineers to keep updated with the latest engineering information, knowledge and techniques. For example, for new design simulation tools, new prototype techniques, new materials and new manufacturing processes. Periodically, design skills or techniques require learning or renewing, such as with CAD or FEA. Thus, the Engineering Department in the companies studied have the most expensive and intensive training compared to the other departments within the organisation. This was discovered during the initial investigations into the existing training and learning practices of the two different automotive companies for submission 1. Then, the preferred learning styles of engineers were investigated and questionnaire surveys were used, and this qualitative approach is discussed next.

2.2.3 Questionnaire Surveys

Detailed surveys were conducted at Company X, in order to gain an understanding of engineers' learning style preferences and whether tailored e-learning solutions needed to be developed for different groups of engineers. Thus, the author wanted to establish which techniques were available to make their learning more effective, and whether Design Engineers, Project Engineers and Team Leaders have different learning style preferences to other Professionals, as well as to each other. To examine these issues, primary data was collected using questionnaires to determine the engineers' various learning style preferences. Two proven questionnaires were selected after investigation and discussion with academic staff at WMG. One was an established questionnaire devised by Honey & Mumford (1992) that was adapted from Kolb's learning cycle (1984), and the other was developed from the latter by Felder (1996).

The reason why two questionnaires were selected was because the author believed that Honey & Mumford's questionnaire was limiting, as it categorises people by having a high, average or low activist, reflector, theorist and pragmatist learning style preference. Yet engineers, due to their nature and requirements in development environments, will adopt each of these different learning styles and their characteristics, as discovered from the surveys. However, Felder's questionnaire provided a more balanced approach with its learning styles as they are paired: active & reflective; sensing & intuitive; visual & verbal; and sequential & global. For example, a high preference for an 'active' learning style indicates a low preference for its corresponding pair, which in this case is 'reflective'. The author was interested in these learning style pairs offered in Felder's questionnaire, as it did not neglect any learning style. The characteristics of each learning style examined are presented in appendix A1. The author left both questionnaires with each engineer for a period of two weeks, in order to give them adequate time to fit filling them in around their workloads, before returning to Company X to collect this data. Statistical analysis methods were performed on this data. Appendix A1 presents a paper where the analysis and findings were published, which was in a peer-reviewed journal titled 'Journal of Workplace Learning', and this helped test the acceptability of the results.

From Honey & Mumford's questionnaire there was no significant learning style shown as the results were evenly distributed. From Felder's questionnaire, the analysis showed that all engineers at Company X do have a significant visual learning style preference compared to other professionals, but not to each other. Therefore, the evidence suggested that there is not a need to having different learning and training methods for design engineers and for more senior engineers, such as team leaders. Other than the visual preferred style of learning, the analysis showed that there is not a significant difference between the other learning styles of engineers and the rest of the professional population. This project work was written up in submission 1. The surveys were repeated a year later on a similar set of engineers at Company Y and again at Company X to check the consistency of the results, and the both sets of results were comparable to the initial findings. Section 4.1.3 discusses learning styles within the framework and the importance of incorporating visual techniques when developing learning and training content for engineers.

2.2.4 Interviews

Interviewing key stakeholders provided the benefit of gathering richer primary data that supported the questionnaire surveys and case studies. Furthermore, interviewing helped provide explanations of the purpose and requirements of the questionnaire surveys to the relevant personnel and answered their queries immediately. Follow-up telephone conversations and emails clarified any outstanding or overlooked issues for the author from the initial face-to-face interviews or from the questionnaire surveys. For example, during the period the questionnaires were left at company X many engineers contacted the author and complained that there were a few ambiguous sentences that they could not answer. The author reassured the engineers that there was no right or wrong answers to either of the questionnaires, and that they only needed to have a slight preference with one choice over the other to select it. Also assurance was given to the engineers that their results were for research purposes only and would not be used for any kind of company assessment of them.

Combining quantitative surveys with qualitative interviews provided an increased understanding for the author and so strengthened the investigations. The investigations reported in submission 5 involved collaborating with e-learning stakeholders in both Company X and WMG, in order to discuss design and development issues with key people. Section 3.2 identifies the roles of the key stakeholders interviewed and their responsibilities in developing an e-learning activity or complete programme.

2.2.5 Literature Research & Review

Although relevant literature was examined and reviewed for all of the submissions, the main literature research and reviews were documented in submission 2, where the investigations identified TBL tools and techniques. The reason why this was done after submission 1 was because the author first needed to understand current engineering training methods and learning style preferences before investigating the enabling technologies to support and enhance these.

The secondary data collected for the literature research and reviews came from library books, academic papers, professional journals, conference proceedings, relevant websites, search engine links and threaded discussions in subscribed WBL forums. The initial background information came primarily from books or academic papers for studying well-established learning factors such as instructional principles. This was the main research activity for submission 2 and provided the main structure for the philosophy side of the e-learning framework. Then, subsequent literature research and reviews came from professional journals, such as the Institute of Engineering & Technology (IET) Journal as well as from technical and educational journals, for investigating current issues such as the enabling technologies and the progress of e-learning in industry. Supporting or specific information additionally came from conference and journal papers, as well as from discussion forums. However, threaded discussions are often people's opinions and not as rigorous as information in books, papers or journals, but they do provide good impressions of the current e-learning products available as well as give useful Web links. To keep the author abreast of new e-learning developments and emerging technologies, further literature research and reviews were conducted on a continual monthly basis and incorporated in the submissions and in this Executive Summary. For example, new e-learning technologies that were not available at the time of writing submission 2 are described in section 4.4. Additionally, chapter 6.0 discusses the current JISC (Joint Information Systems Committee) E-learning Programme and its associated projects, which have areas of similarity to the author's research.

Whilst researching the e-learning literature, the author found that areas of information required filtering to ascertain the most current and appropriate material, as there were often overlaps and contradictions within the literature. This was particularly apparent when reading technical information that was over two years old, especially from books where Web capabilities were described, such as bandwidths and standards, but this illustrates how fast this area of research advances. Thus, the majority of the literature researched on current technologies, came from journals and papers as these are generally published faster than books. Peer reviews and feedback came from academia and industry on the author's own published papers, submissions and presentations at conferences. Collaborative discussions also provided feedback to the author whilst attending relevant workshops, seminars and trade shows, as well as networking at conferences. Much of the literature review and feedback reinforced the author's own findings, which identified that existing e-learning research was fragmented and emanated from predominantly the educationalists' or technologists' perspectives. For instance, e-learning technologists are interested in physical Web-based tools, whereas educationalists are concerned with humanistic and theoretical sides of learning, and there is little evidence of bringing these together. This was typified by the presence of these types of delegate at the ED-MEDIA 2003 conference, where the author was one of the minority discussing e-learning applications. However, the limited number of e-learning applications that were presented focused mainly on general academic environments and not on engineering environments. Additionally, and most importantly, there was little indication on how the different factors in e-learning integrated or complemented each other, and so this and the latter statement identified the areas that needed further investigations by the author. Thus, through researching the published literature, reinforced by attending the ED-MEDIA conference, it was apparent to the author that there were limited integrations between e-learning factors and specific e-learning applications for engineers. Hence, the author concluded that there were gaps in the existing research. After attending the EDMEDIA conference, the investigations continued into exploring factors that provided effective means to facilitate, support and enhance e-learning in engineering development environments.

The various learning factors investigated were grouped into philosopy, delivery, management or technology areas depending on their functionality. These areas subsequently made up categories within the e-learning framework. Chapter 4.0 describes the learning factors investigated within the framework's categories, and draws upon examples from the case studies. First, Chapter 3.0 discusses the context in which the e-learning framework operates to assist e-learning providers develop e-learning activities.

3.0 E-LEARNING FRAMEWORK CONTEXT

This chapter discusses the rationale for adopting a framework to assist in the development and deployment of various activities that contribute to providing effective e-learning content. First the question of 'why' a framework has been employed as the e-learning mechanism is explained in section 3.1. The main e-learning stakeholders addressed by the framework are identified in section 3.2, and section 3.3 elaborates on 'what' is the application context of the framework. Finally 'how' the framework is utilised with guidelines is presented in section 3.4. Chapter 4.0 then details important areas of the framework's development and the learning factors incorporated within its categories.

3.1 Framework Rationale

The case studies and the literature review identified that the majority of e-learning content has lacked coherent integration with various factors affecting e-learning environments. Consequently, particular learning activities can be harmonised but there has been little consistency in providing an effective, holistic e-learning solution that integrates different factors within learning philosophies, delivery mechanisms, management facilities and enabling technologies. This was reinforced by the ED-MEDIA 2003 conference as discussed in section 2.2.5, where delegates focused on their areas of expertise with little evidence of how these areas were incorporated as part of a wider solution. The literature also identified that technology-led solutions have often controlled e-learning developments, which invariably fail to deliver fully (Ravet & Layte, 1997). This was typified by the experience of the WMG case study. Often different technologies are imposed on the developments instead of the technologies being selected and designed to support factors within the e-learning activities. Ismail (2002) points outs that this can lead to e-learning developments ending up as technical projects virtually untouched by the stakeholders. Thus, technology needs to be selected to fit the e-learning activities being developed, by considering the initial learning content with factors from appropriate learning philosophies, delivery mechanisms and management facilities. Therefore, the author concluded that what was required is a way, i.e. an e-learning mechanism, to help combine different learning factors and guide e-learning providers through these factors to generate effective e-learning activities. Developing a methodology, model or framework emerged as the answer for being the e-learning mechanism to assist group, guide and appropriately integrate the various learning factors for developing the required e-learning content. This development and the guidance can be complex because of the changing and varied learning content, and the difficulty in categorising and then prioritising disparate learning factors, as well as keeping up-to-date with constant advances in technology. Assessing these concerns led the author to adopt a framework. The investigations into a framework's characteristics found it to be more flexible than a methodology or model, because different learning factors can be selected to satisfy different learning requirements. Also, not all learning factors need to be selected with a framework. A methodology generally works within set boundaries and a model gives repeatable sequences for a simple scenario, whereas a framework can have many dissimilar sequences and map a variety of methodologies and models (Avison & Fitzgerald, 1995; Mingers & Gill, 1997). This chapter discusses the context and functionality in which the e-learning framework operates, and describes the linking and ordering of factors that have contributed to its composition and architecture. Although the factors investigated are ones that affect engineering development environments, they are not necessarily exclusive to these environments, but have provided practical case study applications to validate areas of the framework. Therefore, utilising a framework as the e-learning mechanism provides:

- **A wrapper to group dissimilar factors together:** The framework groups various factors that impact on the e-learning environment into different categories, according to their function, whilst relating to the necessary learning content. These categories are illustrated in figure 3-1 and the factors within these are detailed in chapter 4.0. Essentially, factors are attributes within each of the categories, and features are attributes of a factor. For example, 'delivery' is a category and 'learning mode' is a factor within the delivery category, and 'self-directed' is a feature of the 'learning mode' factor. The factors can consist of different principles, theories, methodologies, processes, models and techniques, and the framework groups these unrelated factors under the respective category. Avison & Fitzgerald (1995) describe a framework as consisting of these typical types of factors. Also a framework does not need to be fully defined in its construction because it can evolve by improving or changing (Avison & Fitzgerald, 1995), nor do all the learning factors need to be considered. The factors may not be directly comparable or even applied in the same sequence for different applications. This is because there can be many paths through the framework depending on the particular learning requirements and the learning activity being developed. Section 3.4 describes the main paths through the developed framework. This provides generic guidelines for e-learning providers to assist them develop effective e-learning content, which takes into account different factors within learning philosophies, delivery methods and management facilities, as well as the technological capabilities.

- **Multi-dimensional models:** Different models within the framework can be used to represent different e-learning scenarios that lead to the desired learning outcomes for engineers. The models are dependent on the learning requirements, and are discussed further in section 3.3. There are different combinations of features within the learning factors in the philosophy, delivery, management and technology categories of the framework, in order to develop appropriate e-learning content to satisfy the learning requirements. Mingers & Gill (1997) refer to the term 'multi-methodology' to describe linking together parts of methodologies from different categories. The framework factors can be selected to create customised activities to meet different engineering requirements, and these are illustrated in table B-1 in appendix B Chapter 4.0 describes the learning factors incorporated within the framework's categories.

- **Bottom-up architecture:** The framework's layout and structure supports and links its categories. The initial learning content and requirements provide the 'foundation block' for the framework. The philosophy, delivery and management categories represent 'supporting pillars' connecting the foundation block to the roof. The e-learning environment and the stakeholders are represented by the roof, which is the 'upper supporting cover' that connects to the outside world and interacts with external influences. Technology provides the linked capabilities between the philosophy and delivery categories, and between the management and delivery categories, and this is represented as 'connecting ties' between the pillars. The architecture is illustrated in figure 3-1.

Figure 3-1 identifies the main learning factors in the framework's categories for designing and developing an e-learning activity or a complete e-learning programme, and these factors are described in chapter 4.0. This framework has been updated from earlier submissions to incorporate directional flow arrows to assist in guiding the e-learning provider through the framework's architecture and categories more effectively. The categories have been numbered to clarify the paths through the framework as described in section 3.4. The framework colours provide a visual aid when referring to its different areas and categories in this chapter and in chapter 4.0. The colour key is shown below:

ORANGE	=	Learning Content & Requirements
GREEN	=	Philosophy Category
PURPLE	=	Delivery Category
CYAN	=	Management Category
GREY	=	Technology Category
YELLOW	=	Stakeholders

The construction of the e-learning framework builds from, adds to and consolidates the various factors investigated in this research. In summary, the purpose of the framework is to help guide and facilitate the decisions of e-learning providers, with regard to the choice and design of each feature within a learning factor for an e-learning activity. In this context, e-learning providers comprise, not only of Instructional Developers, tutors or trainers, but service, technology and content providers. The next section discusses these different e-learning providers and their roles and responsibility within the e-learning development.

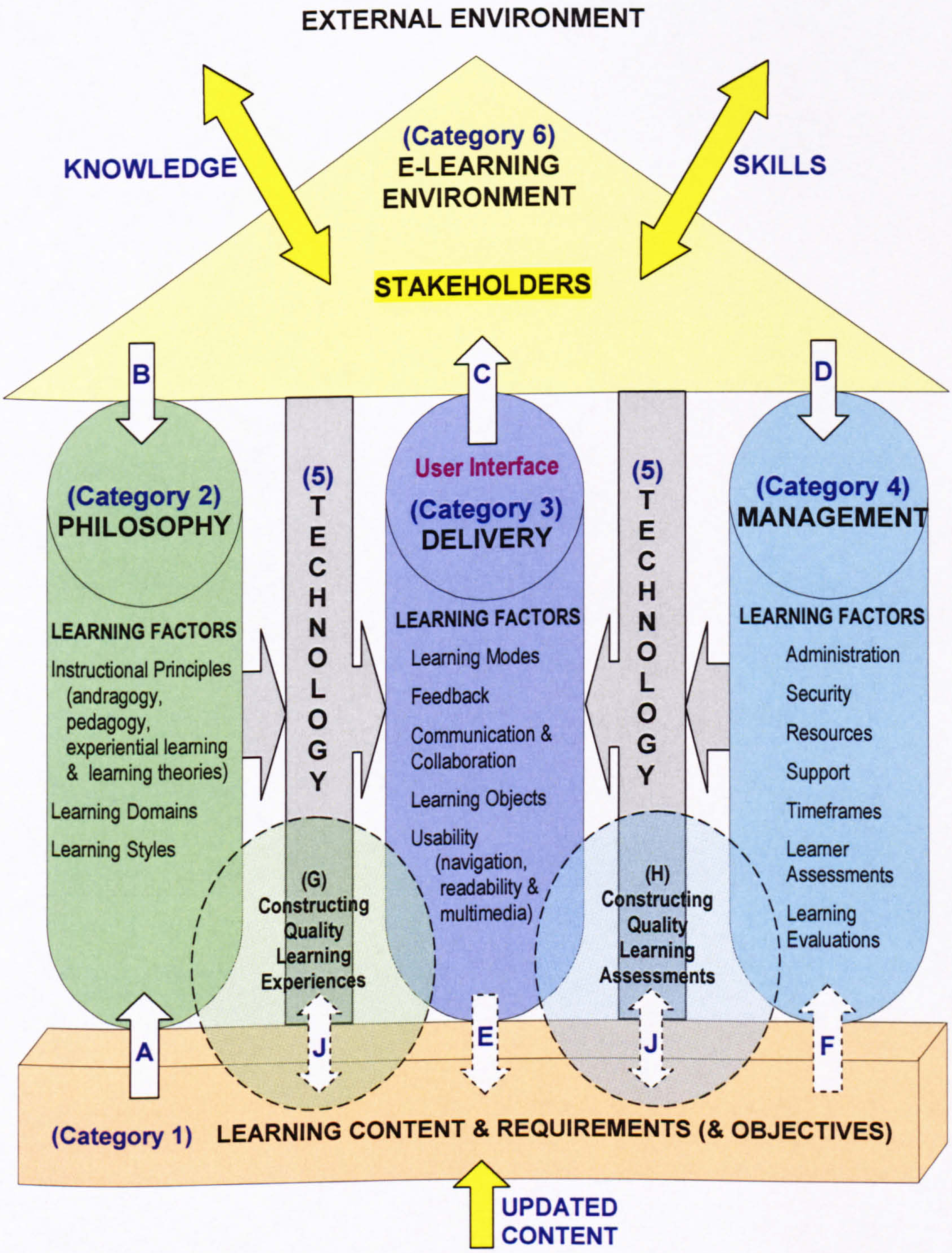


Figure 3-1: Framework for the Design & Development of E-learning Content (updated James-Gordon, 2003, 2004a)

3.2 Different Stakeholders in E-learning

This section discusses the context in which different e-learning stakeholders operate within the organisations studied, in order to identify and appraise the various responsibilities they have with an e-learning development. The stakeholders investigated were divided into two categories: 'e-learning consumers' - those who require and use e-learning content, and 'e-learning providers' - those who make e-learning possible. The consumers of e-learning are basically the 'learners' seeking knowledge or requiring skills, whether they are engineering students in a learning establishment such as WMG, or professional engineers in an organisation such as Company X. The e-learning providers investigated were:

- **Content providers** who are subject matter experts that produce the initial content material, and instructors who deliver the content to the learners. At WMG, the Module Tutor is normally both the subject matter expert and the instructor. Content providers need to liaise with technology providers, to assist them with the electronic delivery and management of their content.

- **Technology providers** who are either hardware or software providers. Hardware providers are not detailed in this document but they can provide 'off-the-shelf' technology or add to existing systems. Instructional Developers come under software providers, which are Web-developers, graphic designers and programmers. Instructional Developers are responsible for the electronic representation and delivery of the content via an appropriate user interface. The WMG case study revealed that this responsibility is presently shared between their Instructional Developers and E-Lab, a subset of University of Warwick's IT Services department.

- **Service providers** who consist of hosting providers, but can also be technology providers that work under the IT department in organisations. At WMG, this is now the responsibility of E-Lab.

- **Administrators** who are responsible for organising learning or training schedules, and resources such as classrooms, instructors, equipment, session times and pricing. WMG has administrators dedicated to the post-graduate MSc programmes. Presently, Company X relies on the Systems Administrator to arrange any training done via computers, such as CAD, FEA and Microsoft Project Management training.

- **Managers** who are responsible for promoting, guiding and co-ordinating the development of learning programmes. In industry, these managers are generally from HR or training departments, but in Company X this is again presently the Systems Administrator's responsibility. In academia, these managers are heads of department or course programme heads, and in WMG case, this is the MSc's Course Head and the WMG case study predominately focused on the E2BM full-time MSc.

The main connections between the e-learning stakeholders are illustrated in figure 3-2. The involvement of the stakeholders is important at all stages of the design and development of e-learning content, not only because they can contribute to their part of the development, but they are more readily accepting of any changes made (Steed; 1999; French et al, 1999). Stakeholder involvement is an important CSF, as point (1) in section 5.2 identifies. Table B-1 in appendix B illustrates different stakeholder involvement within the various engineering e-learning applications studied.

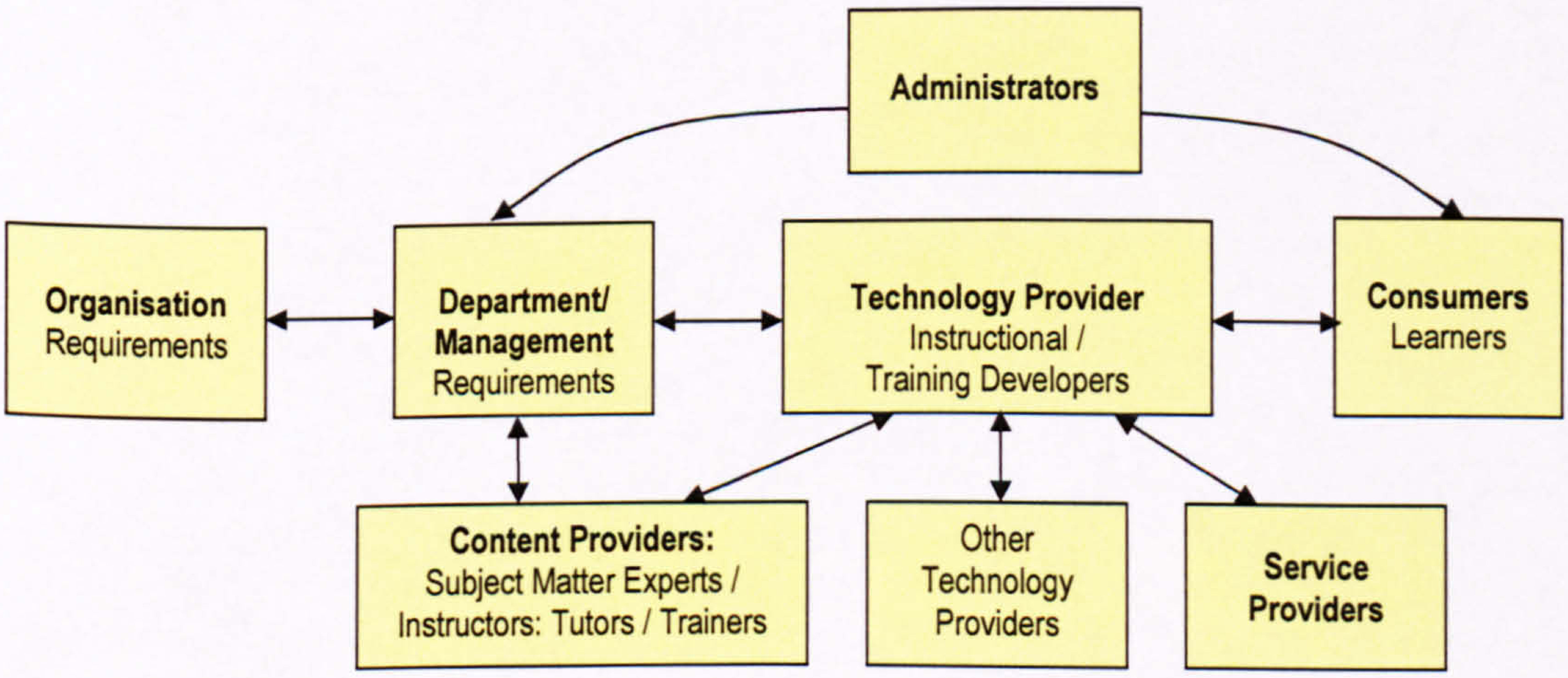


Figure 3-2: Connections between E-learning Stakeholders

Senior e-learning decision makers, i.e. the management team, are more likely to have commitment and participation from their providers, i.e. instructors and developers, if the providers are actively involved with the initial as well as on-going discussions for an e-learning programme development (Gupta et al, 2000; Steed; 1999). However, this can depend on the organisation's culture and its attitude to learning.

The industrial case studies revealed that most managers did encourage learning and viewed it, not only as a requirement for the job, but also as part of their employee's personal development. However, a problem encountered at Company Y was that a few managers found it hard to accept learning at work, except for dedicated training courses necessary to do the job, such as for CAD, and left the responsibility for their employees' training entirely to the HR department. Company Y's HR Manager knew this attitude existed with a few of their managers and was investigating Management & Leadership seminars. According to Rosenfeld & Wilson (1999), *"an ongoing career development is possible when initiatives both from the management as well as from the employee himself or herself are brought into action"*. Thus, the responsibility for learning needs to be equally shared by engineering managers and employees.

Company X recognised that their engineers are more motivated in training and self-development plans, if they are stakeholders in their own learning process. Additionally, within an industrial environment such as Company X, the instructors and Systems Administrator often take into account the engineers' skills profile, which identifies existing knowledge and prior experiences, and so the learning activities developed tend to be customised and thus learner-oriented. Also, the instructor acts more like a coach or advisor to the engineer and the Systems Administrator can advise on technical issues. The learning content developed at Company X, not only is customised to the engineer's requirements, but can also be tailored to the work team's needs by incorporating specific project related content. The proposed e-learning environment at Company

X will have shared responsibility between their engineers, instructors and Systems Administrator for its future e-learning content development, once management approval has been obtained.

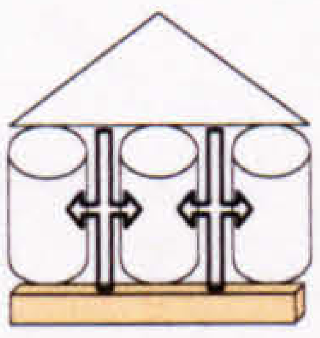
In academia, the development of traditional course content, as well as e-learning content, has rarely involved the students' inputs or desires, as experienced with the WMG case study. This is because students are often initially less informed about what is available, what is expected of them, and what they need to know. Thus, the learning experiences for students at WMG have tended to be predominantly tutor-centric. Knowles (1984) associates this to pedagogy, which assumes that learners have little or no prior knowledge, and this is further discussed in section 4.1.1.1. However, Module Tutors at WMG do retrospectively modify their content for their next instructor-led sessions based on reactive evaluation from students' feedback recorded on Module Review forms. This represents the first level of the Kirkpatrick's evaluation model (Kirkpatrick, 1996) and is described further in section 4.3.6.

Once an organisation understands its learning consumers, the providers can begin to identify what type of content needs to be created to satisfy the learning requirements. The complexity and functionality of e-learning will be determined by the type of content, whether its use is for retrieving engineering information as with Company X, or instructional exercises as with WMG, or a combination of both.

Through the use of the e-learning framework, e-learning providers can work together to effectively select and sequence the required learning factors to create activities for developing the e-learning content. The next section discusses the various engineering e-learning activities based on different learning content and requirements that are necessary. This provides the initial starting point for developing e-learning content, and so provides the foundation block for the framework.

3.3 Engineering E-learning Scenarios

This section discusses 'what' context the framework can be utilised in, and explains areas where the case studied engineering applications have helped to develop and test the e-learning framework. The applications were not conclusive but represented the diversity of engineering environments that have planned, developed and implemented e-learning in varying degrees. Different learning content and requirements are needed for such environments, and these are first discussed in sub-section 3.3.1. Then sub-section 3.3.2 explains instructional objectives which provide the detail to the learning requirements. The development of e-learning content is made up of e-learning activities which are dependent on the objectives. Section 3.3.3 describes the integration of different learning activities for engineers, mainly for their immediate and structured learning needs. The case study applications were reported in submission 5, but the main investigations are discussed in this section.



3.3.1 Learning Content & Requirements

The initial learning content material and requirements need to be established before considering other categories of the framework. This is so that an understanding can be gained of what the learning requirements are aiming to achieve, prior to deciding what possible enhancements, support and/ or e-enablers can improve the learning content by considering its philosophy, delivery, management and technology aspects. Developing effective e-learning content involves starting with the basic content material needing to be learnt and then identifying how e-learning activities can facilitate this. The overall learning requirements lead to producing specific learning objectives which influence the development of the learning activities. Therefore, designing and developing e-learning content is not a single task, but a complex process that involves many different factors within the framework's categories. These factors inter-relate with the philosophy and management aspects of e-learning as well as the delivery mechanism using appropriate technologies, as illustrated in the developed framework of figure 3-1. However, depending on the specific learning objectives the relative mix of the framework's factors can vary to produce different learning models. In this context, a learning model is a set sequence through the framework for developing improved e-learning content, from the specific learning requirements and from the initial learning material. The case studies identified three main learning requirement areas for developing content:

1) Immediate task-specific skill to learn
2) Structured general-knowledge to learn
3) A combination of immediate and structured learning

The investigations revealed that Company X primarily practises point (1), as the majority of their content consists of engineering information that is required to be learnt immediately for the task at hand. WMG mainly practises point (2) by having standard educational lessons and PMA work that develops and applies this knowledge, often to work-based situations. Nevertheless, WMG has tailored company-specific MSc courses as well as providing standard MSc courses to students. Likewise, Company X provides standard CAD training to new engineering graduate recruits and tailored CAD training for engineers with existing CAD skills. Additionally, Company X proposed an e-learning environment development which is an Intranet knowledge-base that aims to incorporate their engineers' collective product design knowledge. This plans to consist of design methods and reasoning, lessons learnt, design calculations and supplier capabilities, as well as having refresher knowledge to re-affirm certain engineering principles with worked examples. Submission 5 revealed that Cisco Systems practises point (3) by having a mixture of specific tasks for immediately requirements and structured self-development activities. Figure 3-3 has been developed by the author to illustrate traditional connections of information content to specific skills-based training and to general knowledge-based learning in industry and academia respectively.

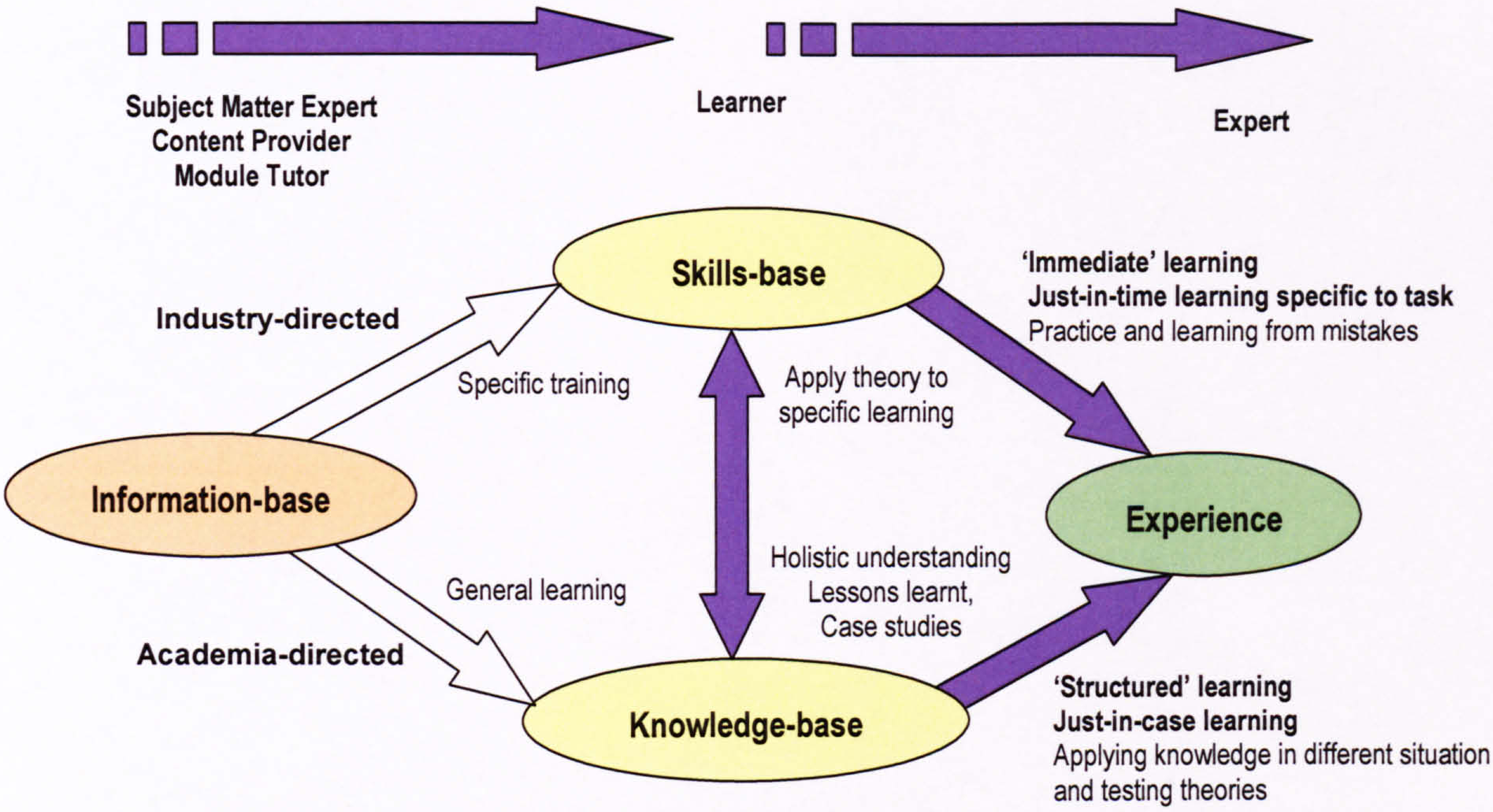


Figure 3-3: Traditional Connections of Learning Content (James-Gordon, 2004a)

If the 'immediate' learning requirements in industry for JIT skills and the 'structured' learning requirements in academia for more transferable knowledge are combined appropriately, then practical continuous life-long learning can be holistically provided. Mihal et al (2003) comment that this integration *"will not only require a perfect balance between skills and knowledge, but will focus these attributes upon the fulfilment of a specific mission or higher purpose"*. Section 3.3.3 discusses this need for integration further. The investigations examined different learning requirements for engineers, and the following list illustrates examples of these:

- **New content needing to be introduced by an induction lesson.** For example, pre-module course work being provided by WMG to help enable students reach the same knowledge-level, prior to module lessons. In industry, this can be a preview of company information provided to new employees in their induction week, as experienced at Company X.

- **Current content requiring to be recalled by a refresher lesson.** For example, a refresher CAD training course at Company X is requested if an engineer has not used the software for more than six months.

- **Needing to acquire a new skill for a required task.** For example, learning the functionality of a CAD software package in order to design and develop products at Company X.
- **Needing to become more competent by practising.** For example, after the initial CAD training course, the engineer continues self-directed learning with the CAD's functionality whilst producing useful engineering designs.
- **Needing to pass a test or gain a qualification.** For example, gaining a post-graduate MSc degree at WMG.
- **Needing to experience different learning situations.** For example, obtaining practical experience with the CAD system at Company X by doing different work-based tasks. Conversely, gaining experience with a different CAD system for a similar work-based task.

This list of engineering learning requirements provides the purpose of the learning content to be developed. The next section identifies instructional objectives for different learning activities, and these in turn provide the specific details for the learning requirements as well as define the desired outcomes from the learning activity.

3.3.2 Instructional Objectives

The instructional objectives provide separate goals that the learner needs to achieve in order to satisfy the learning requirements. The objectives help to identify what type, level and range of learning activities are necessary for the learner to complete, in order to gain the necessary knowledge or skills to become competent. Hence, the objectives provide learning boundaries for the learner, and so learning activities are derived from these objectives. Instructional objectives incorporate desired learning outcomes, which can range from being task specific information for acquiring a skill, to general information for constructing knowledge. Therefore put simply, learning requirements define the purpose of the learning, objectives define how to achieve specific learning requirements, and outcomes define the broader aspects of learning and what the learner acquires the ability to do after completing the learning activities. The terms 'instructional objectives' and 'learning objectives' are interchangeable in this document. However, the author predominantly uses instructional objectives for a specific or measurable learning activity, and describes learning objectives for a broader level that takes into account the learner's holistic needs and/ or organisational requirements.

Instructional objectives are normally set by the content providers who provide Instructional Developers with the basis of how the instruction is to be designed and how the learning outcomes required to be assessed. This was demonstrated at WMG, and students needed to then meet these objectives in order to progress and complete the module lessons. Instructional objectives need to be aligned to the business objectives to ensure the success of an entire e-learning programme (Phillips, 1997). These objectives are important CSFs which are identified as points (3) and (7) in section 5.1. Considerations for setting instructional objectives were reported in submission 2, but Steed (1999) identifies four main considerations as:

- **Clearly stated outcomes**, with no ambiguity given to learners of what is expected of them. The outcomes need to state what the desired learning activity will accomplish, and can contain the expected duration, milestones and timeframes. These latter considerations are discussed further in section 4.3.4.
- **Measurable performance criteria,** which indicate to the learners and the instructors, when desired level of performance or understanding has been reached. This can be incorporated prior to self assessments or instructor-led tests. Learner assessments are described in section 4.3.5.

- **Relevance.** The objectives need to be in context and have relevance to the learning required, which can be an academic project or a work-based task. Section 4.1.2 describes the relevance of content as a level of the affective learning domain.
- **Links to assessments**. Post-assessments can test the learner's competency, which identifies what has been understood and the learner's ability to master the tasks, as well as determining if the instructional objectives have been met. Pre-assessments test the learner's existing knowledge before embarking on an e-learning activity, so that the e-learning content can be customised to suit the learner's experience and abilities. Learner assessments are discussed further in section 4.3.5.

The development of effective e-learning activities needs to incorporate these considerations in the instructional objectives. Table 3-1 illustrates specific learning activities under generic learning requirements of the case studies investigated, and these represent different learning models within the framework.

Table 3-1: Specific Learning Activities of Different Engineering E-learning Applications

	E-LEARNING APPLICATIONS CASE STUDIES						
	COMPANY X			WMG		CISCO SYSTEMS	
Learning Requirements (Learning Models)	Immediate Task Specific			Structured Knowledge		Immediate & Structured	
Learning Activities (that form the developed content) (with instructional objectives that incorporate desired learning outcomes)	1) Self-directed Engineering Information	2) Customised CAD Training	3) Standard CAD Training	4) Standard Educational Lesson	5) Post Module Assignment	6) Customised Work-based Task	7) Self-development

The following list identifies each of the learning activities in table 3-1 and provides an example of a desired engineering learning outcome. These outcomes are defined within the overall objectives, and describe what is expected to be achieved by the engineer once the learning activity is completed:

1) **Self-directed Engineering Information:** After working through lessons learnt & bending moment calculations from previous chassis designs, the engineer will have the ability to apply this information to a new design model.

2) **Customised CAD Training:** After the lesson and exercise, the engineer will demonstrate his or her ability to manipulate imported surfaces for engine ports.

3) **Standard CAD Training:** After the lesson and exercise, the engineer will have the ability to generate basic surface features.

4) **Standard Educational Lesson:** At the end of the lesson, the student will have the ability to differentiate between asset-led and market-led marketing.

5) **Post Module Assignment:** After completing point (4), the theory of the two marketing concepts can be applied to a specific case within a company and the case study investigations will be written up.

6) **Customised Work-based Task:** Preparation and presentation to peers will help explain the benefits of a technical process from a business perspective for senior managers to understand. This will strengthen the learning gained from the task.

7) **Self-development:** After the first leadership lesson, the Principle Engineer will have the ability to apply the steps learnt towards achieving effective collaboration within the design team.

The case studies investigated had such outcomes defined within their instructional objectives of the learning activities. The activities in points (2) to (5) were either outlined in pre-requisite information packs or they were presented as part of the introductory lesson made by the instructor. However, the learning activities in points (1), (6) and (7) were either self-instigated or outlined in workload plans by the engineer's manager. WMG additionally presented each module's instructional objectives online for their students, and Cisco Systems had developed a learning portal for each employee to access his or her own personal development learning plans.

Traditionally in an academic environment such as WMG, the final outcome from structured learning activities is to achieve a recognised qualification, and in industry learning activities are often necessary to complete the immediate workplace task. The next section discusses combining different learning content to predominantly satisfy immediate task-specific and structured knowledge engineering learning requirements.

3.3.3 Integrating Learning Content

Industry can be reluctant to provide training for their workforce that is not delivered immediately and relevant to the required task. Thus, learning in the workplace has often concentrated on providing JIT task-specific activities, and the development of wider, transferable knowledge-based learning has often been the responsibility of academia. Nevertheless, Thoben & Schwesig (2002) comment that industry requires engineers who have the breadth of basic knowledge but still are able to gain specific skills when necessary to deal with various problem-solving activities.

The demands of the changing workplace require engineers to have a range of up-to-date competencies. Consequently, this requires them to constantly renew and expand their knowledge and skills to keep themselves current and maintain their value to the organisation. Acquiring engineering knowledge and applying it, traditionally has been a linear progression, where the learning process occurs before applying the new knowledge in a practical situation. However, engineering learning and application are becoming more tightly connected to meet the demands of the workplace and for continuous professional development (Fink & Holifield, 2004). Thus, learning is becoming more of an integral part of the workplace and not just the responsibility of academia. Thus, the distinctions between learning and working activities are increasingly blurred, and this concurrent learning and working engineering environment is shown in Company X.

Modern engineering activities are also more collaborative and multi-disciplined (Tenopir & King, 2004), and as Denning (1992) points out engineers need to be skilled listeners and negotiators for dealing with suppliers and customers, as well as rigorous in management functions. Thus, competencies are required in areas such as communication, project management and other soft skills as discussed in chapter 1.0, in order for engineers to work collaboratively as well as independently on problem-solving activities.

E-learning can help develop activities for competency-based learning as well as course-based learning, but Longmire et al (2000) state the *"challenge in implementing competency-based learning is the lack of appropriate content that is sufficiently modular"*. 'Learning objects', which are manageable bite-sized amounts of e-learning content, can facilitate a more competency-based learning approach by matching the object's meta-data with individual's competency gaps (Brennan et al, 2001). Learning objects are described further in section 4.2.4. Additionally, learning objects can provide 'just-enough' content to satisfy JIT learning, by assisting in the acquisition, retention and recall of only the learning content required for the immediate task-specific activity. Thus, e-learning content can be developed more efficiently by adopting learning objects that are assembled to create activities within the e-learning content which are tailored to individual learning requirements. This leads to improving the quality of learning experiences by providing learner-specific content that appropriately combines discrete learning objects from different areas within knowledge-bases and skills-bases, and connects to information-bases. Learning objects can also assist in creating e-learning content for specific groups of learners.

Therefore, an e-learning environment can be developed differently for each engineer, team, department or organisation, depending on the existing knowledge and skills of engineers as well as the learning requirements. Different engineering profiles can provide groups of students or engineers to be categorised and then offered tailored e-learning activities. Streaming students had been introduced to some extent at WMG, as students with technical backgrounds took more business related lessons, and visa versa. Nevertheless, the content level was not streamed, and students with some business or technical knowledge had to sit through all the lectures, even the initial introductory lessons. However, company 'specific' MSc programmes offered at WMG had some tailored content for their students, based on the company's requirements and the students' abilities, and this is described further in section 4.1.1.1. Although WMG had yet to develop customised e-learning content using specific reusable learning objects, their Instructional Developers were aware of the benefits of learning objects and had begun to adopt a more modular approach in their content development. Consequently, learning activities at WMG were beginning to become more learner-oriented. Manton et al (2002) comment that this enables students to work against the model of tutor-sequenced learning to determine their own self-directed sequence of learning, which can benefit learners with different knowledge and skill sets, and strengths or weaknesses, to balance their education and competencies.

Different content type, level and range can be integrated to provide the relevant competencies required for engineers and/ or their organisation. The content characteristics investigated are summarised as being:

- **The type of content required**, either for:
  - An 'information-base', i.e. data that is collected in context and provides a repository for housing this information. For example, engineering formulae, material specification, design standards (British Standards - BS 308), preferred suppliers names and contact details, lessons learnt and best practices.

- A 'knowledge-base', i.e. academic theory or information in context. For example, recalling specific lessons learnt and calculations from a previous project and applying these to the current project.
- A 'skills-base', i.e. the know-how required for a specific task and its practical application with the consequences recorded. For example, recalling best practises from a previous project.

- **The level of e-learning instruction applied in organisations,** from being content-centric to learner-centric. For example, general tutor-sequenced content to customised specific learner-oriented content.
- **The learning material needed for different situations,** ranging from 'immediate' or JIT content to 'structured' or just-in-case content.

The case studies identified an increasing need for professional and student engineers to combine different content type, level and range to help provide wider, transferable, relevant competencies for their own self-development as well as for tackling specific tasks. Integrating these different content characteristics provides variations from structured, generic, content-specific, knowledge-based activities to immediate, customised, learner-specific, skills-based activities, to cater for the different engineering learning requirements.

Experiences from lessons learnt and best practices can be recorded and fed-back to information-bases to be recalled when required for either JIT skills or structured knowledge. For example, an engineer can search an information-base to recall an engineering principle or terminology, or to seek further explanation whilst in the middle of an engineering calculation. Consequently, figure 3-4 builds from figure 3-3 to integrate the relevant knowledge-base and skills-base learning content as required.

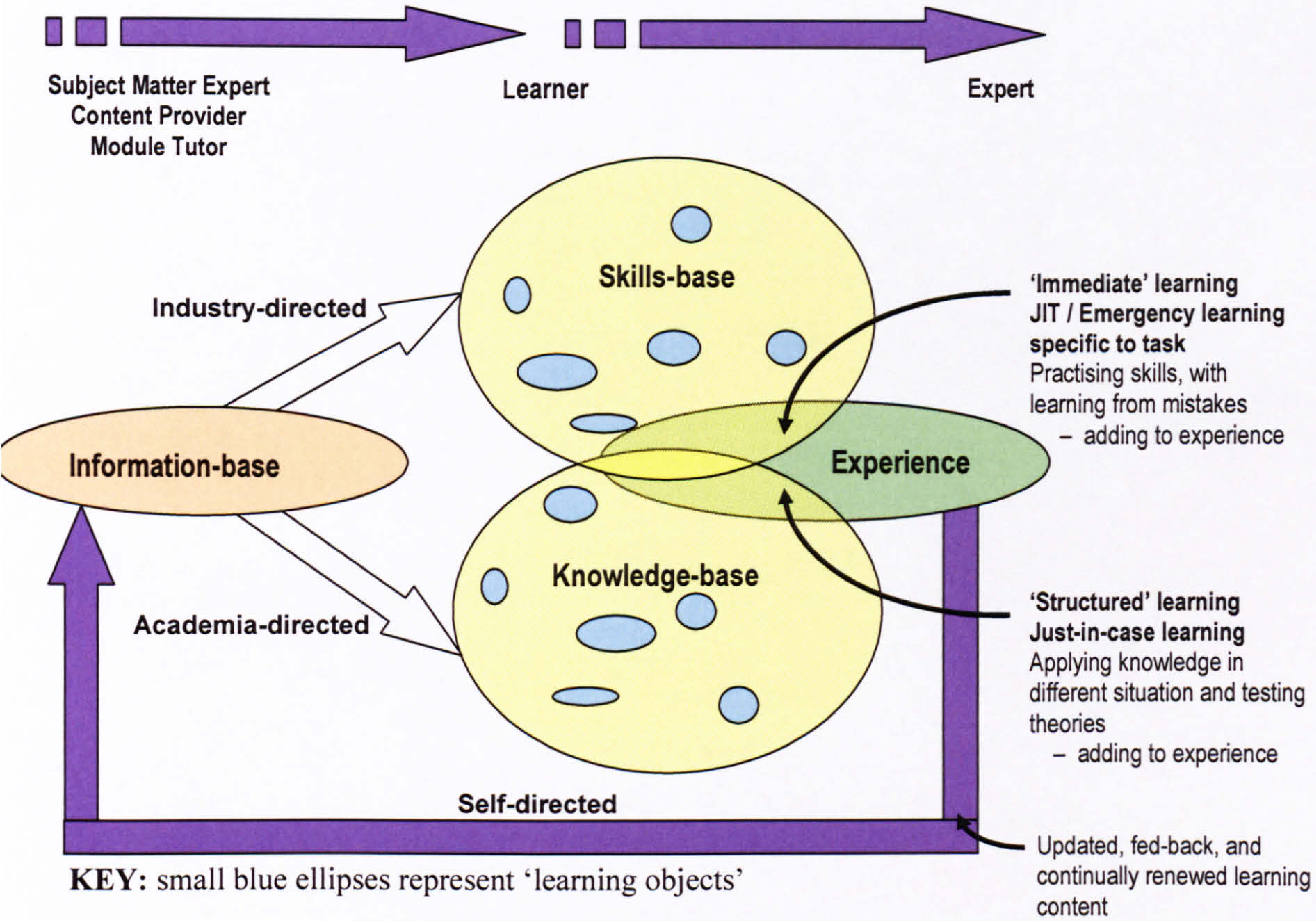


Figure 3-4: Integrated Connections of Learning Content (James-Gordon, 2004a)

Once the initial content and learning requirements are established, other learning factors in the e-learning framework can be structured, linked and ordered to create activities for developing effective e-learning content. There are different combinations of features within the learning factors in the philosophy, delivery, management, and technology categories of the framework. The next section identifies paths through the framework's categories to integrate the different learning factors for developing the e-learning content to satisfy a particular e-learning application. Thus, the next section presents generic guidelines for using the framework. Table B-1 in appendix B presents a matrix identifying learning factors to be considered when developing different engineering e-learning applications.

3.4 Framework Guidelines

This section describes the context of 'how' the framework can be utilised. The framework groups various factors that impact on the e-learning environment into philosophy, delivery, management or technology category according to their function. A 'typical' path through the framework is identified to guide e-learning providers through its categories and to assist them select appropriate learning factors to develop the basic learning content by incorporating e-learning activities.

The path through the framework is described as 'typical' because once in a category there can be many options and combinations of various features within the learning factors to satisfy different learning requirements. This was discussed in the previous section 3.3. However, the entry and exit path of each category follows the same sequence. The stages of this sequence are presented next, which illustrates how the framework is utilised to develop the e-learning content:

- **Stage 1 – Learning Content & Requirements:** The initial substance of the learning content and the main learning requirements are identified before considering the other framework categories that can affect the content. This is so that an understanding can be gained of what the learning requirements are aiming to achieve, prior to deciding what possible enhancements, support and/ or e-enablers can improve the learning content by its philosophy, delivery and management aspects. This first stage can be considered as the framework's foundation block as illustrated in figure 3-5(i), and this category has been discussed in section 3.3.1.

For simplicity in describing the path sequences within the framework, a number has been allocated to each category in the framework:

- Category 1 represents Learning Content & Requirements Category
- Category 2 represents the Philosophy Category
- Category 3 represents the Delivery Category
- Category 4 represents the Management Category
- Category 5 represents the Technology Category
- Category 6 represents the E-learning Environment Category

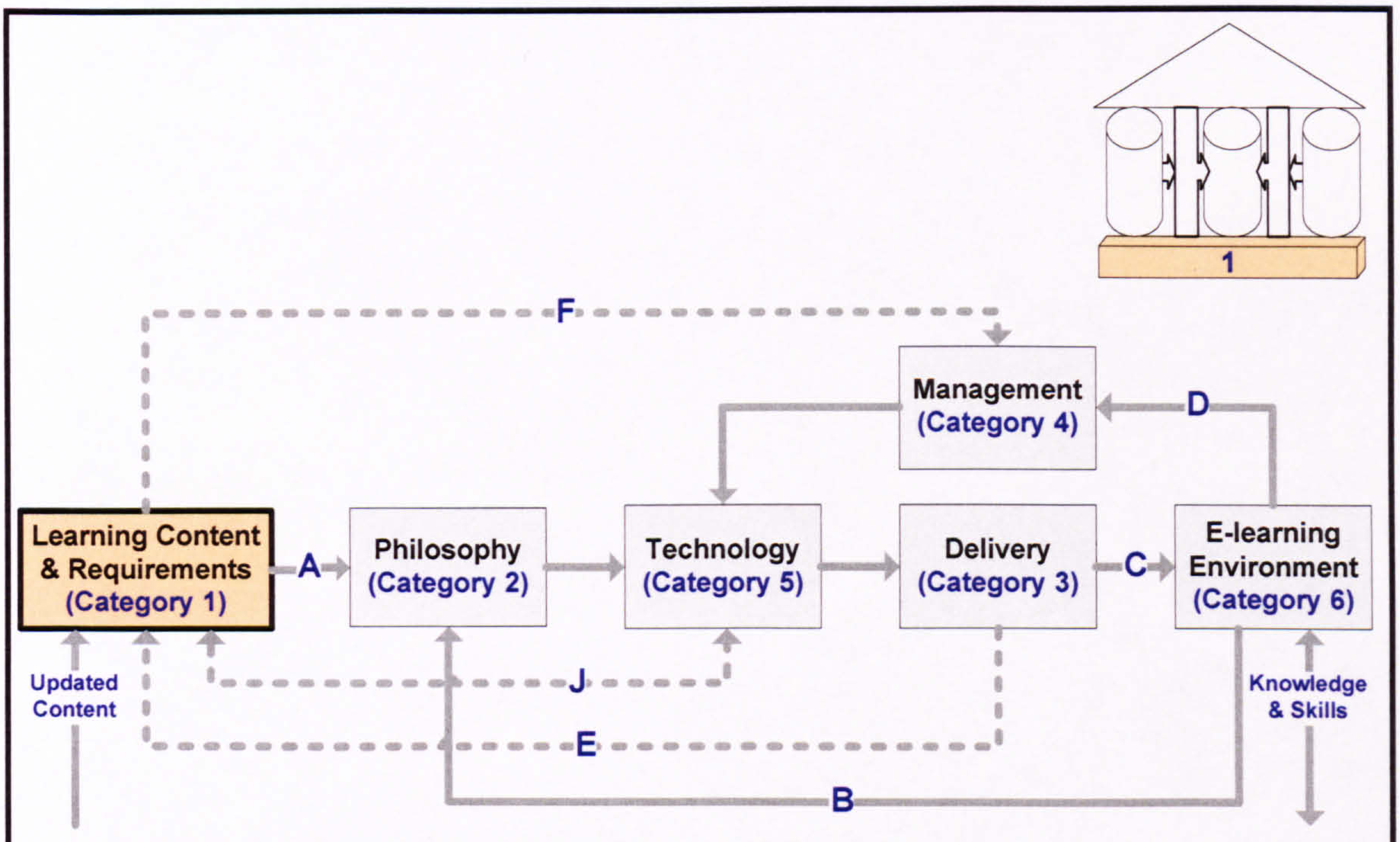


Figure 3-5(i) Framework Guide: Learning Content & Requirements

- **Stage 2 – Philosophy Aspects:** This next stage is to incorporate the philosophy issues affecting the e-learning content development, as shown by the path from category 1 via arrow A to category 2 in figure 3-5(ii). Figure 3-1 identifies the learning factors within the philosophy category of the framework, which are instructional principles, learning domains and learning styles. The philosophy factors are important to the content development as they can assist in enhancing and customising the learning content, and the main factors investigated are described in section 4.1.

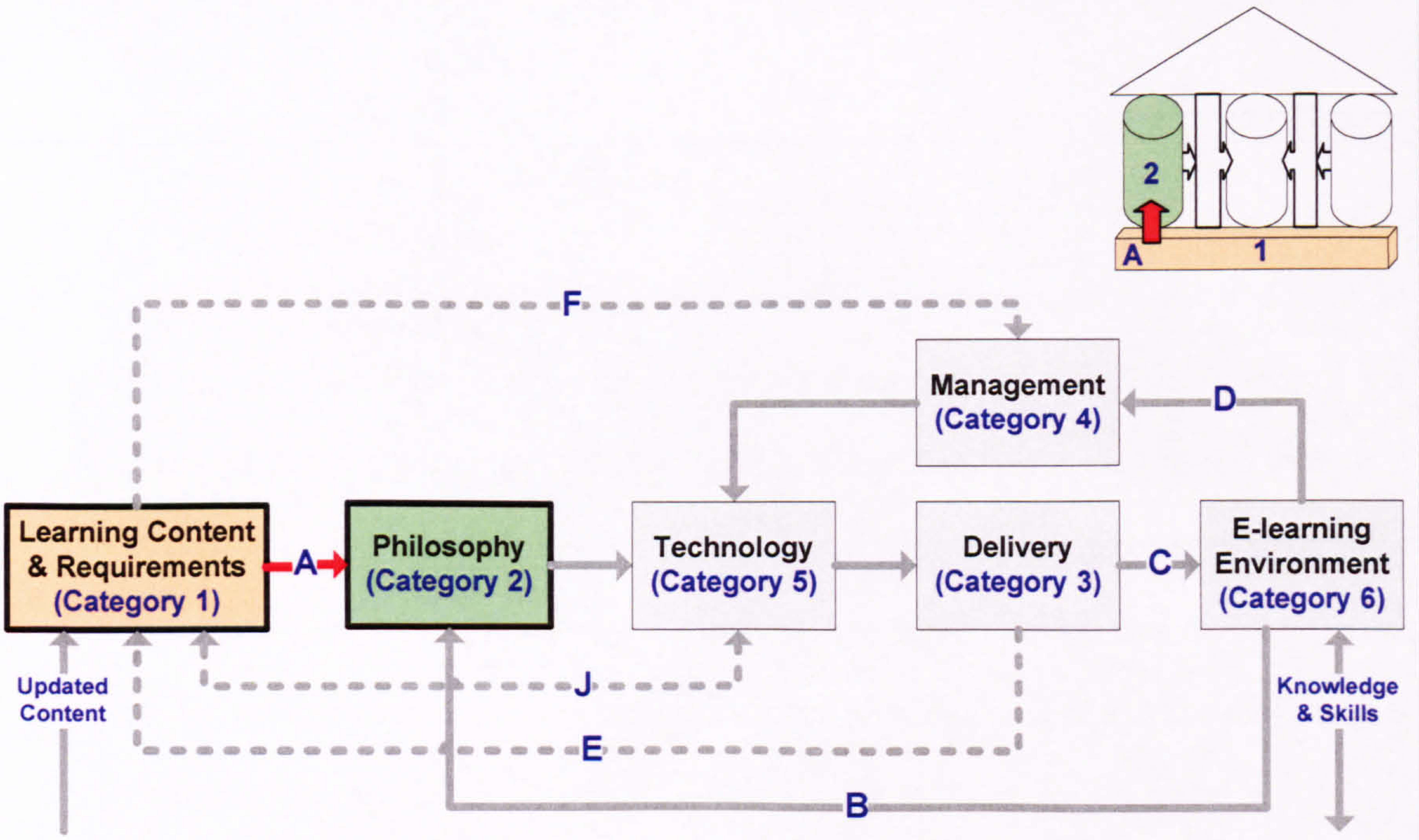


Figure 3-5(ii) Framework Guide: Philosophical Aspects

An aspect of category 2 is that the content can be tailored to suit learners' specific requirements by taking into account their prior experiences. Thus Arrow B in figure 3-5(iii) illustrates connections from existing knowledge and skills in the e-learning environment that feedback to the framework's philosophy category which can affect the development of customised content. This is shown by the path from the e-learning environment, category 6 via arrow B to philosophy, category 2 in figure 3-5(iii).

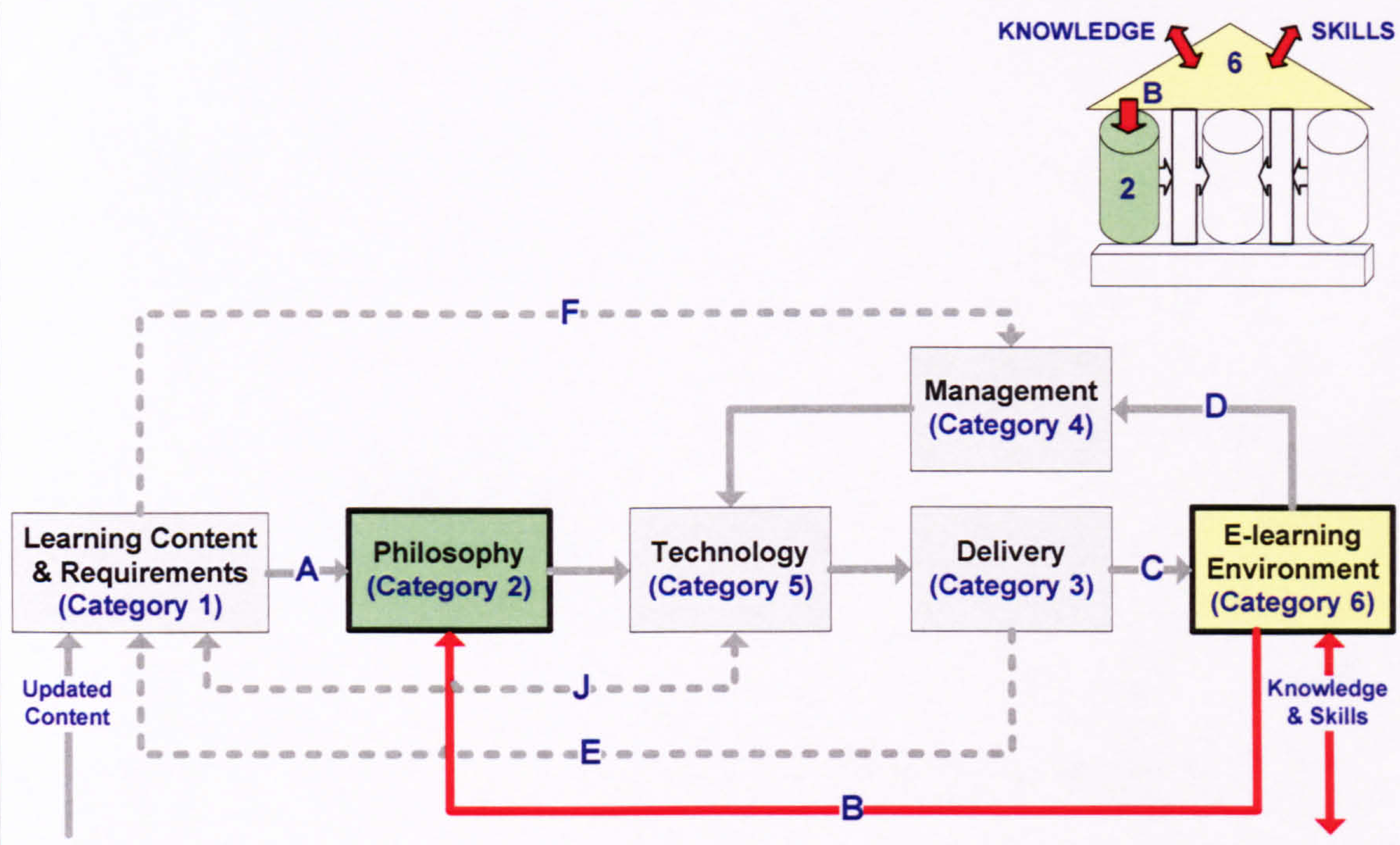


Figure 3-5(iii) Framework Guide: Existing Knowledge & Skills Considerations

- **Stage 3 – Initial Technology Selection:** The path for the initial technology selection is from category 2 to 5 to category 3, as shown in figure 3-5(iv). The technology provides the infrastructure to shape the e-learning content being developed. This contains various Web-based formats, e-learning standards, electronic collaboration tools, commercial software products and bespoke development tools. The technology enables the initial learning content to be developed into e-learning content. The important consideration at this stage is that the technology chosen needs to be aligned to the philosophy factors as well as the content, and not have these fit around the technology capabilities. Further technology related issues are described in section 4.4.

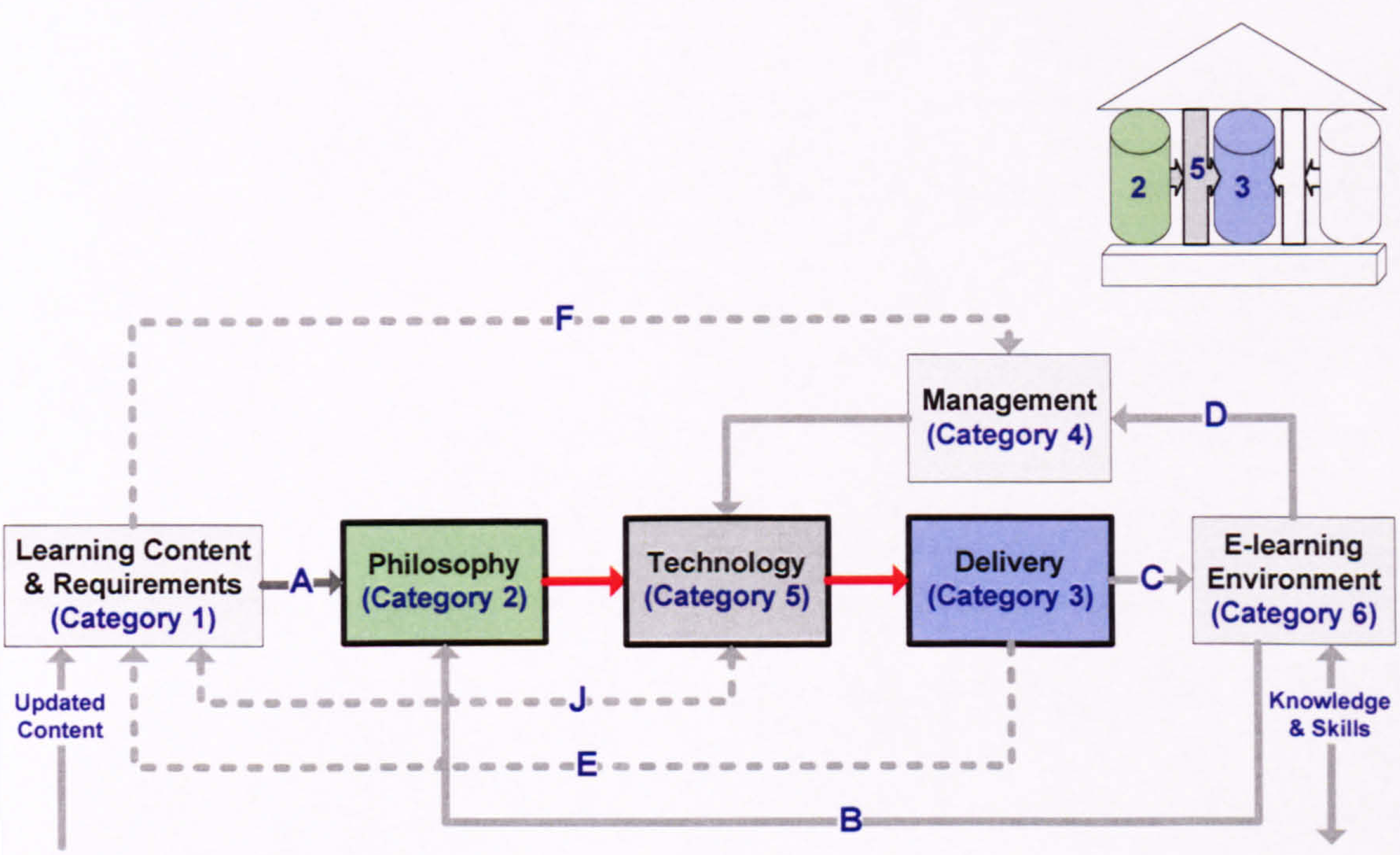


Figure 3-5(iv) Framework Guide: Initial Technology Considerations

- **Stage 4 – Initial E-learning Delivery:** The first delivery of an e-learning activity is shown in figure 3-5(v) by the path from category 3 via arrow C to category 6. Figure 3-1 identifies the delivery learning factors that can be considered and appropriately adopted, which comprise of learning modes, collaboration and feedback techniques, learning objects and usability features. These factors are important in how the content is represented and presented to the learners, and the main issues are described in the delivery category of section 4.2. At this stage, an e-learning activity or lesson can be delivered as a pilot study on a sample of stakeholders to test its functionality. Then, the e-learning providers can determine if the learning experiences have improved, and if the e-learning activities adequately replace or complement existing methods of learning. The capabilities of the new e-learning tools and techniques can also be assessed and modified if required.

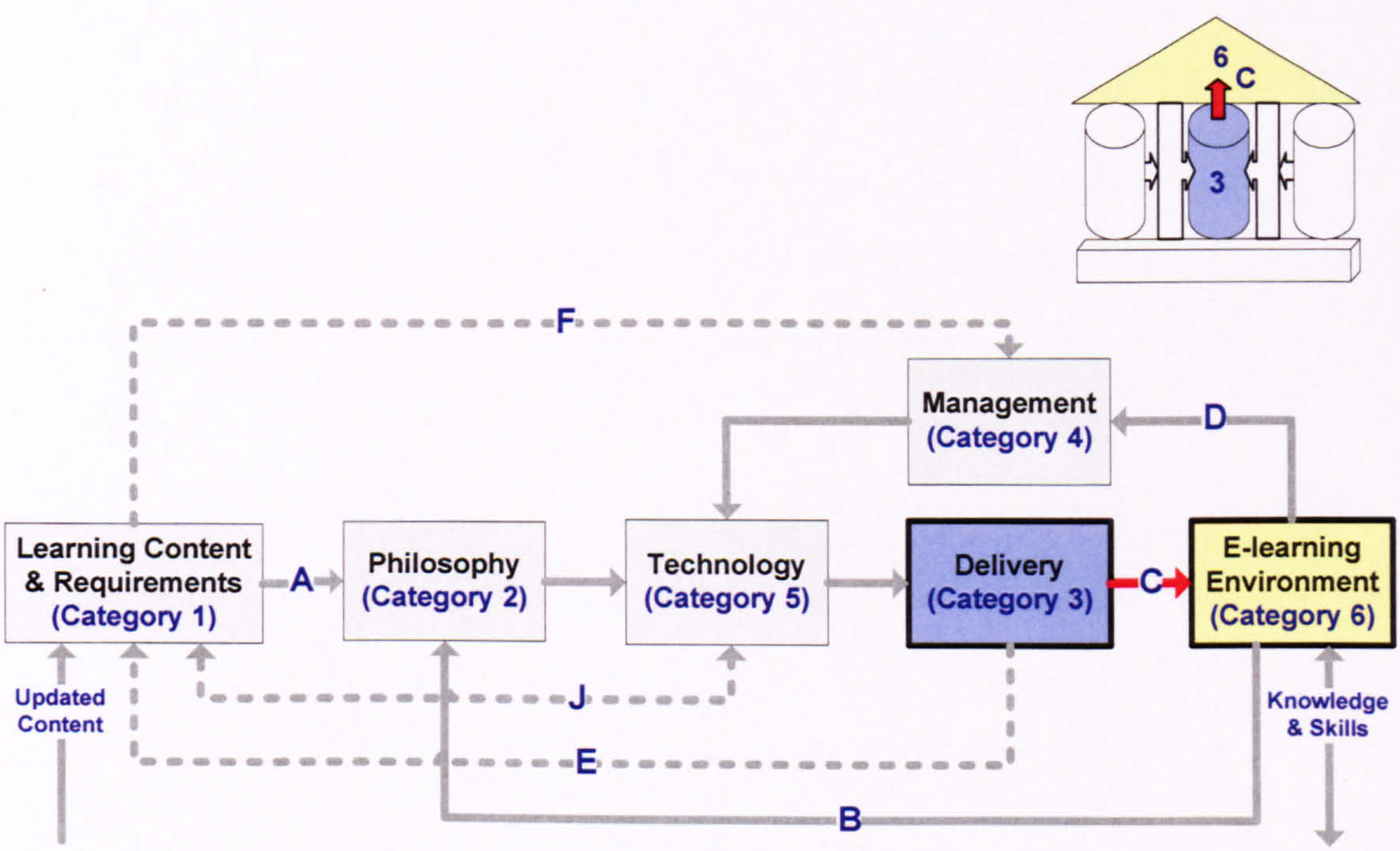


Figure 3-5(v) Framework Guide: Initial E-learning Delivery

Integrating and optimising relevant content, philosophy and delivery factors with appropriate technology, assists in refining and enhancing the content to construct quality learning experiences. Area G on the framework's figure 3-1 identifies this. This is also illustrated on figure 3-5(vi) as the path from category 1 via arrow A through categories 2, 5 and 3, and back to category 1 via the dotted arrow E. This cycle for continuous content improvements can be repeated as required. Arrow E is shown as dotted to differentiate it, and not divert from the main path through the framework.

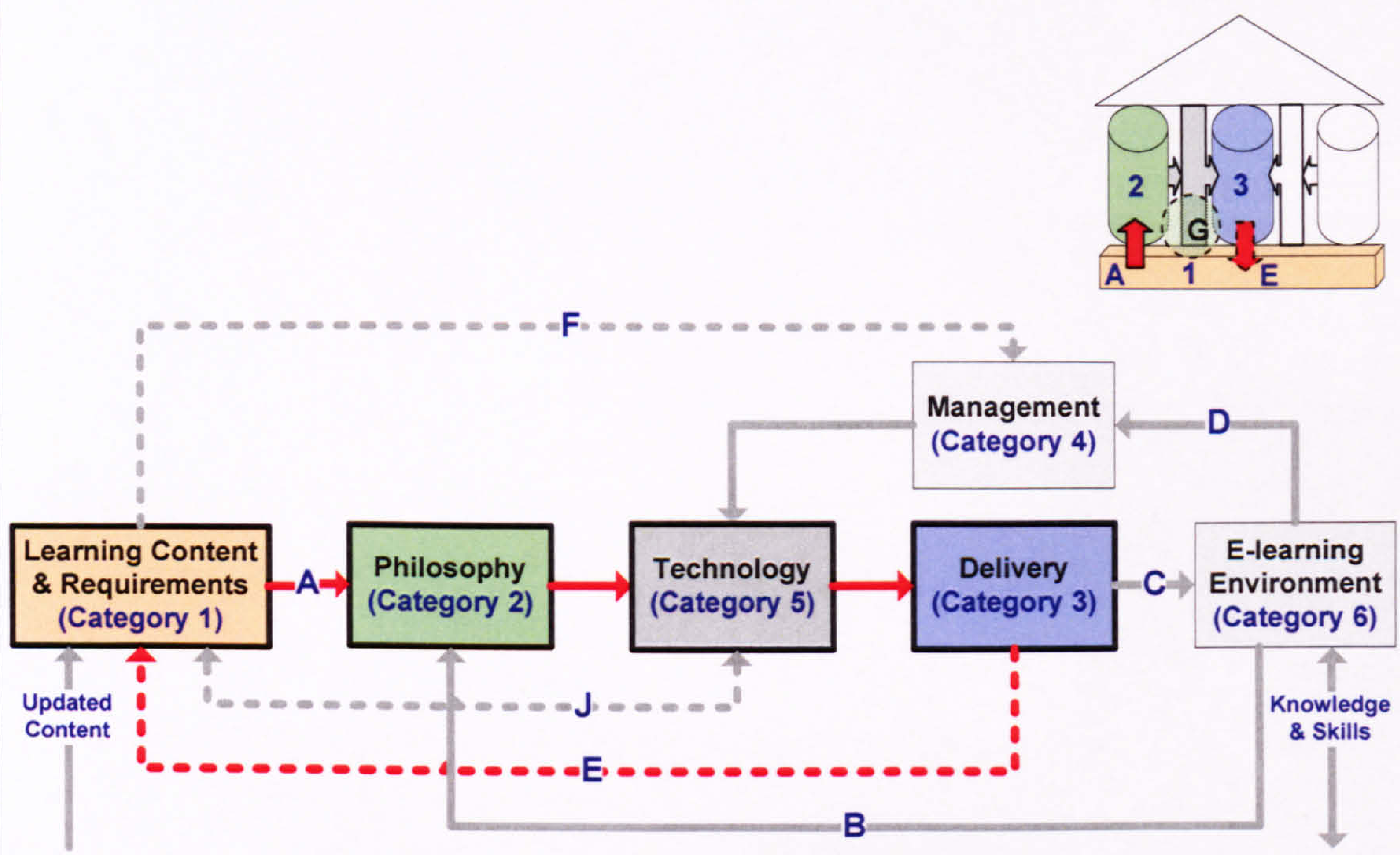


Figure 3-5(vi) Framework Guide: Cyclic Path for Quality Learning Experiences (G)

- **Stage 5 – Management Factors:** This stage considers what management factors can be added to the content development, which can begin with simple administration and support functionalities. This is shown by the path from category 6 via arrow D to category 4 in figure 3-5(vii). Figure 3-1 identifies the management learning factors that can be considered and appropriately adopted, which comprise of administration, security, resources, support, timeframes, learner assessments and learning evaluations. The main management factors are described in section 4.3. Managing security factors such as access control and intellectual property protection are important to protect the learning content. Assessment activities can be added or updated after the pilot running of a lesson.

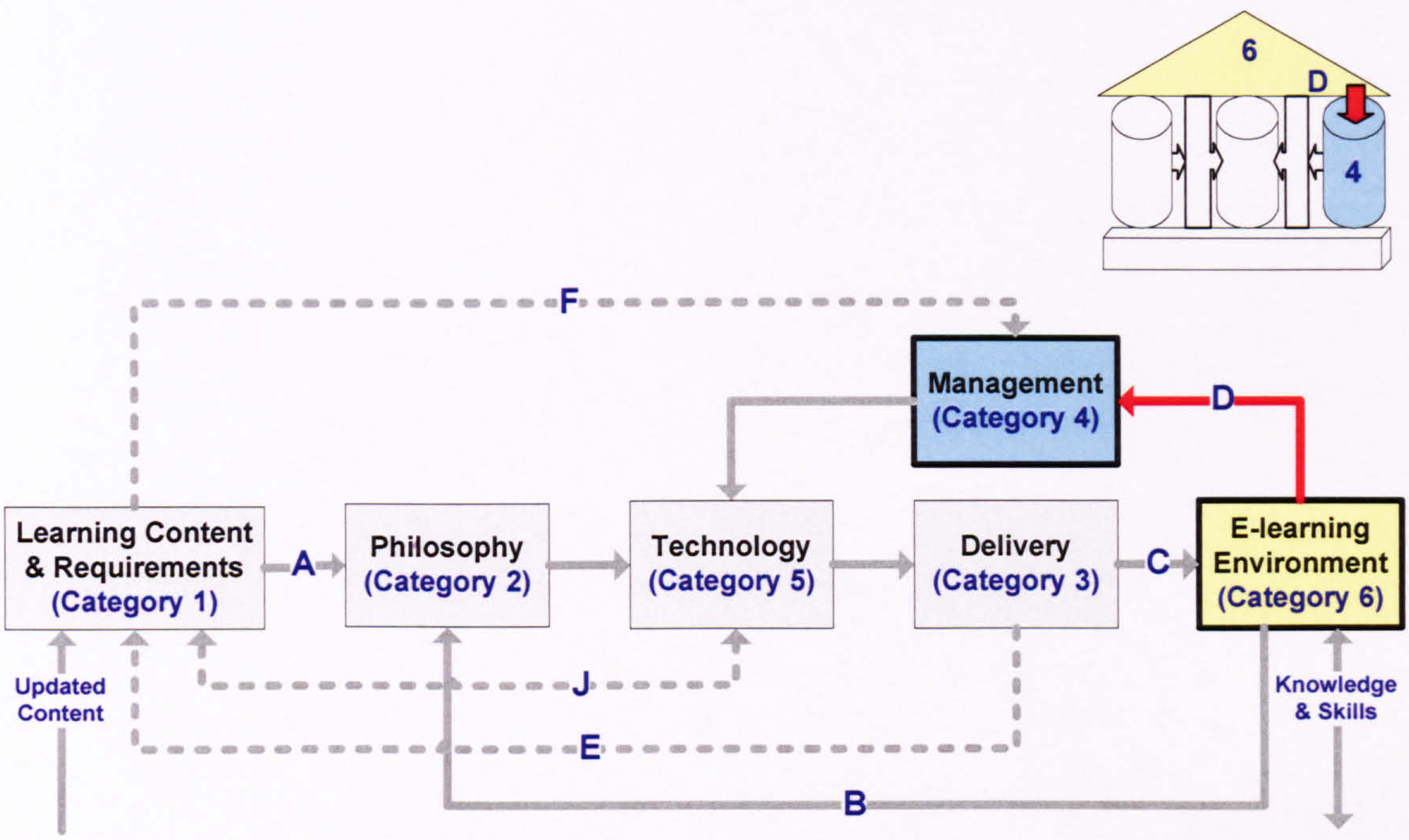


Figure 3-5(vii) Framework Guide: Management Considerations

Stage 6 – Further Technology Selection: The path for the further technology selection is from category 4 to 5 to category 3 in figure 3-5(viii). The important consideration at this stage is that the technology chosen needs to incorporate the management factors in the e-learning development, and not have these fit around the technology capabilities. However, awareness of available technology and its capabilities need to be understood to deliver the content within all stages of the framework. This is so that the design of an e-learning activity does not go beyond the capabilities of the technology, nor compromise the design by under estimating the potential of the technology. For example, knowing the increased bandwidth capabilities over the Web means that video content can be streamed faster. Hence, further adjustment or even re-selection of the technology maybe required once the content has been developed from incorporating the other necessary factors from the framework's categories. Therefore, the framework and guideline figures illustrate arrow J as being bi-directional. Arrow J is dotted to differentiate it and not divert from the main path through the framework.

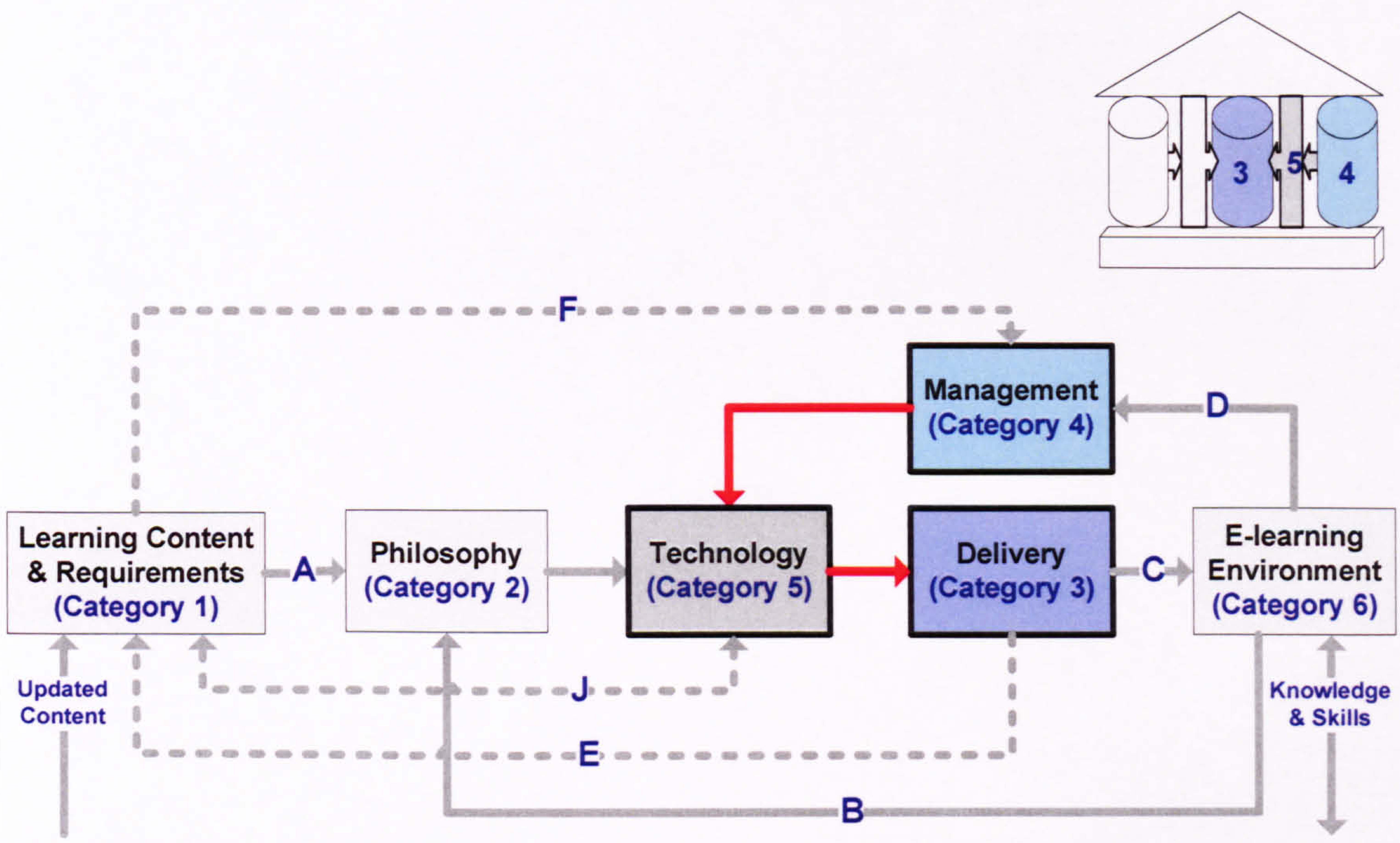


Figure 3-5(viii) Framework Guide: Further Technology Considerations

- **Stage 7 – Further E-learning Delivery:** The delivery factors can be re-examined if necessary, to match the management factors with the enabling technologies selected to suit, e.g. support and assessment functionality in the management category affects the feedback function in the delivery category. Integrating and optimising relevant content, management and delivery factors with appropriate technology further assist in refining and enhancing the learning content, and helps to construct quality learning assessments. Area H on the framework's figure 3-1 identifies this. This is also illustrated on figure 3-5(ix) which shows the path from category 1 via arrow F through categories 4, 5 and 3 and back to category 1 via arrow E for further improvements. Arrow F is dotted to differentiate it and not divert from the main path through the framework.

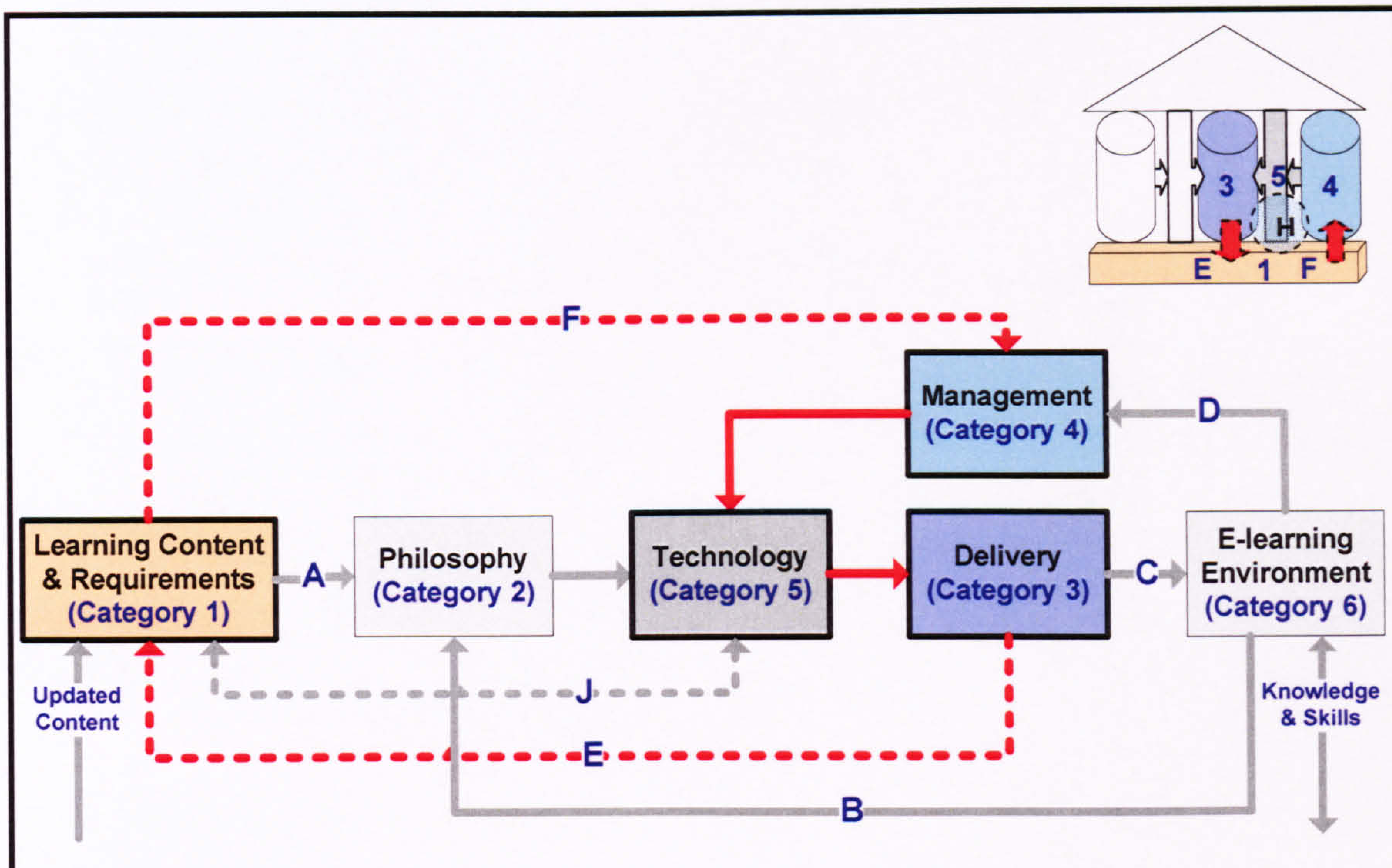


Figure 3-5(ix) Framework Guide: Cyclic Path for Quality Learning Assessments (H)

Further or final considerations for the delivering the e-learning content follows the path from category 3 via arrow C to the e-learning environment category 6 as illustrated in figure 3-5(x).

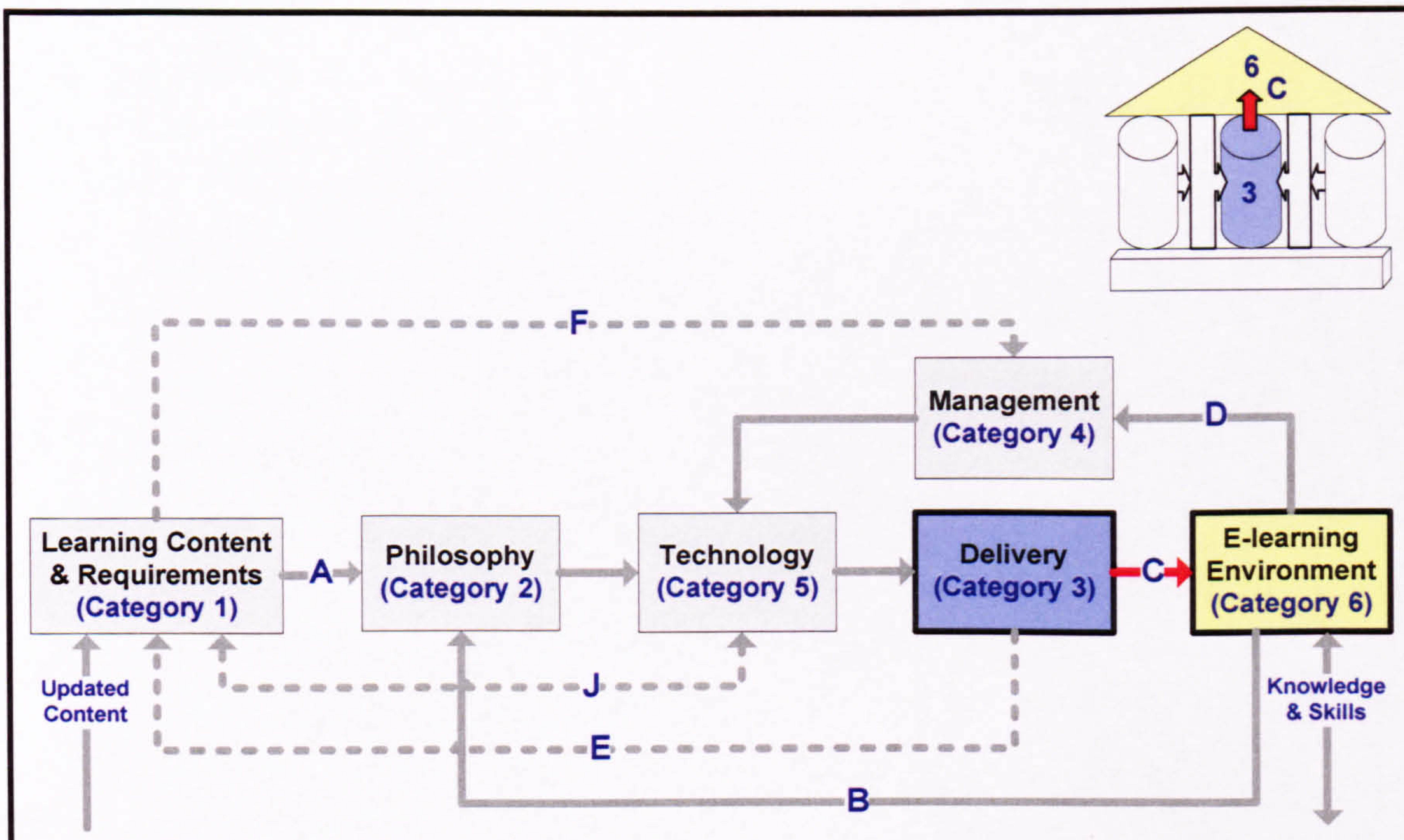


Figure 3-5(x) Framework Guide: Further E-learning Delivery

The complete path through the framework is shown in figure 3-5(xi). Further content refinements from updated content and existing knowledge or skill-sets contribute to the continuous path which encompasses all the former stages. The guidelines represent a 'typical' sequence through each of the categories of the e-learning framework, although the selection of the learning factors within the categories can differ depending on the initial material of the content and the learning requirements. Consequently, the result of utilising the framework is that the learning content is developed more effectively by taking into account the appropriate learning factors within the framework's categories. The learning factors are not detailed in this section due to their many combinations, but chapter 4.0 describes them in more depth within the framework's categories, and where necessary examples are provided from the case studies.

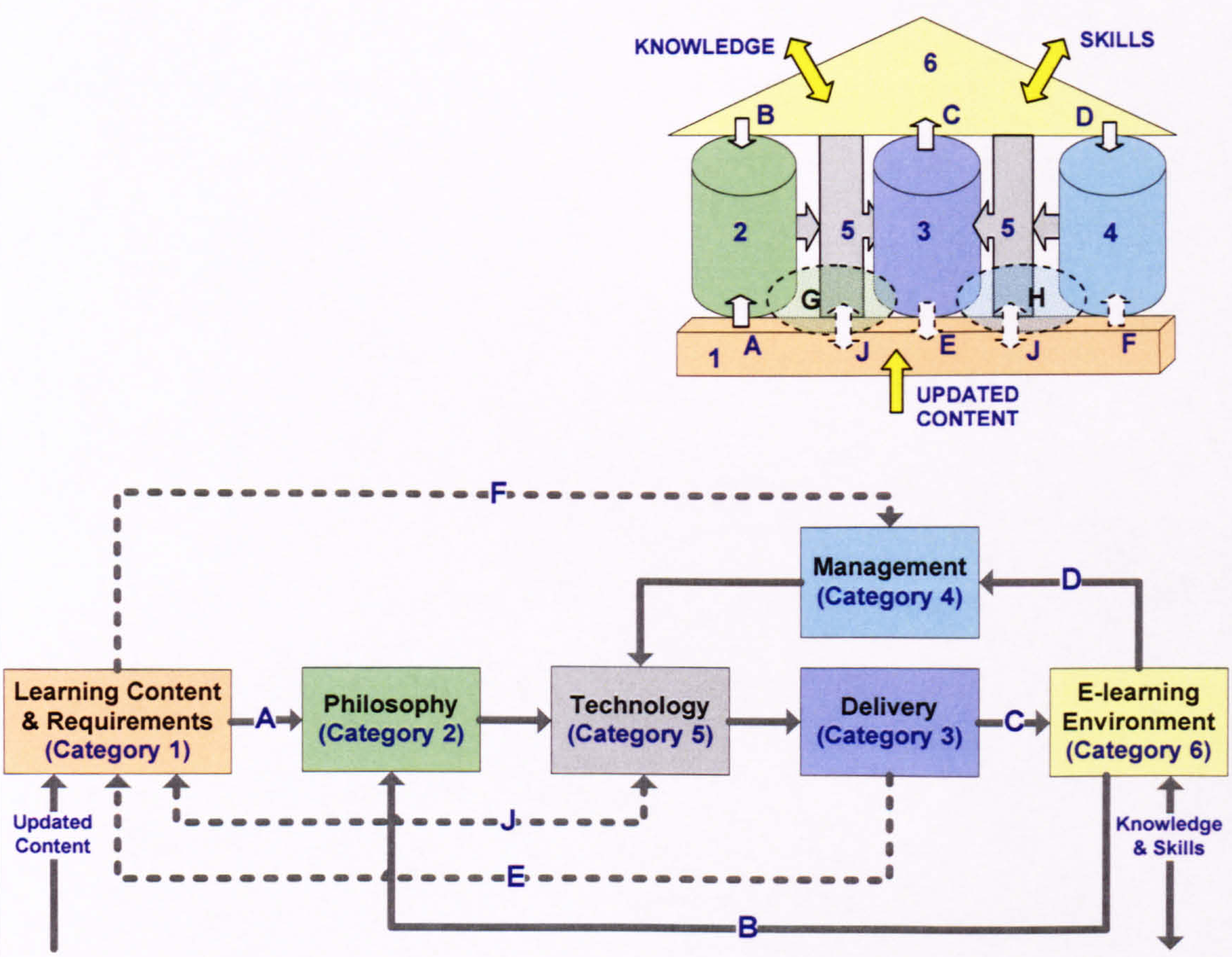


Figure 3-5(xi) Framework Guide: Complete Path Flow through Framework

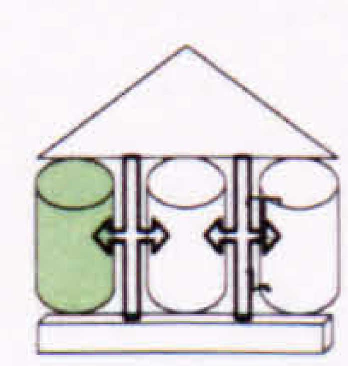
This research highlighted a concern with how e-learning providers develop content to be engaging, in order to enable and encourage learners to process new information, to produce meaning from it, and to continue learning. This can be helped by utilising the framework to match the learning factors against the learning requirements, or more specifically learning objectives, when developing a particular e-learning activity to support or enhance the content. Understanding the learning requirements and individual objectives, has also meant establishing how, what and when the learning providers believe individuals learn. These requirements primarily focused on the learners and the learning process, particularly on the way in which learners receive, organise and retain information. However, as the author explained in submission 4, learning also depends on the attitude, motivation and participation of the learner, as well as the content required to learn. Therefore, the learning approach adopted from the framework has an impact on the content design and development, whether it follows the programmed instruction of the objectivism theory or the problem-solving discovery activities of the constructivism theory. Section 4.1 discusses these approaches further in the philosophy category of the framework. This and other categories that have been important in the framework's development are described next in chapter 4.0. Examples and comparisons are made by referencing the different case studies where applicable. The developed e-learning framework is not designed to be conclusive, but can evolve through further application to produce e-learning solutions for engineers in subsequent e-learning activities, lessons or complete programmes.

4.0 E-LEARNING FRAMEWORK DEVELOPMENT

This chapter describes the main learning factors within each of the framework's categories, which have contributed to the e-learning framework's development. Categories were constructed to group the various disparate learning factors together into specific areas depending on their functionality. These areas became the philosophy, delivery, management or technology categories in the framework. Figure 3-1 illustrates the framework's construction and grouping of learning factors in its categories. The grouping helps to facilitate selecting, linking and ordering of the factors, and fit the appropriate technology to them. Previous project work and findings were consolidated to assist with the framework's development. The purpose of the framework is to provide guidance to e-learning providers through the maze of options of disparate learning factors to develop appropriate e-learning activities to support the learning content.

The selection of learning factors is dependent on the initial learning content material and learning requirements, as discussed in section 3.3.1. The learning factors and their specific features have been investigated and identified through a combination of primary and secondary data collected, information researched and reviewed, knowledge gained from case studies and peers, and the author's experience of engineering. The case study work and experiences are referred to and discussed as required in this chapter. The investigations predominantly focused on factors that enable, support and/or enhance e-learning in the product-development and self-development engineering environments.

4.1 Philosophy Category



The philosophy category contains non-tangible learning factors that can influence and enhance the learning content. The main factors investigated were instructional principles, learning domains and learning styles. The key issues identified through the research are discussed in the following sub-sections.

4.1.1 Instructional Principles

The main instructional principles that affect engineers were brought together in submission 4 from the previous research submissions by the author, and the key factors are described here. These comprise of the pedagogy and andragogy approaches, experiential learning, and objectivism and constructivism learning theories, with the degree of their adoption depending on the learning application, environment and /or prior experiences of the learner. Steed (1999) points out that by building instructional principles into the design of e-learning activities helps to facilitate learner satisfaction, motivation and confidence with the learning activities. This in turn encourages the learner to continue to participate with the learning activity and this is further discussed in section 4.1.2. First, the main instructional principles that have been researched are compared and summarised next.

4.1.1.1 Andragogy & Pedagogy

Daily learning activities in industry are mainly self-directed activities that deal with task-based problems, drawing on existing knowledge and skills to resolve them. Hertzum & Pejtersen (2000) comment that *"engineers normally have a certain degrees of freedom in choosing the way they want to accomplish their work, and they are expected to make informed decisions in a number of situations where many possible solutions are available"*. This was experienced with the Company X case study. Knowles (1984) emphasise that adults are self-directed and bring their existing knowledge to their learning situations as well as take responsibility for their own decisions. Knowles identifies this as adult learning or 'andragogy', and claim it differs from 'pedagogy', which is based on child learning with the assumption that learners have little or no prior knowledge (Knowles, 1984). However, pedagogy is often described in learning philosophies to imply either learning approach. Also, Knowles's work has been challenged by educationalists such as Peter Jarvis (1995) and Mark Tennant (1997), who say that there is no intrinsic difference between the way children and adults learn. Nevertheless, the author uses Knowles' notion to present these two approaches at different ends of the same continuum. As learners mature they generally utilise their previous experiences in learning, identify their own learning requirements, increase their self-directedness and base their learning around immediate problem-solving tasks (Ravet & Layte, 1997). This is observed in engineering, as newly graduated engineers entering the workplace often lack specific skills, but they have the opportunity to put their recently acquired academic knowledge into practice. For example, by liaising with suppliers on product design and manufacturing matters, or working to specific company standards and procedures. Hence, the novice graduate engineer can be considered to begin with the pedagogy approach and progress to the andragogy approach as he or she gains experience and becomes an expert engineer. Therefore, by applying the andragogy approach, the design of e-learning content can be enhanced in the following areas:

- **Instruction that is task-oriented:** Learning activities can be designed in context with the required tasks being performed. The case studies identified that task-based exercises are the norm in industry, such as those experienced within Company X. Task-based sessions also have been utilised in the post-graduate module's syndicate activities at WMG, to put into practise the theories taught in the classroom lessons.

- **Explanations about why specific things are being taught:** Instructional objectives provide the reasoning for why specific learning activities are taking place and what the outcomes are likely to be. Post-graduate modules at WMG and CAD exercises at Company X present the objectives in the first few pages of the course manuals. For example, in a WMG marketing module: *"In this lesson you will learn about market segmentation. This will enable you to differentiate your target market"*. An example in a CAD exercise: *"In this lesson you will learn how to construct fillet edges on solid and surface models. This will enable you to remove all sharp edges and burrs from your designed product"*. Section 3.3.2 discussed instructional objectives and provided further examples.

- **Instruction that caters for the range of learners' backgrounds:** Learning activities can be designed to cater for different expertise levels and take into account existing skills and knowledge, and prior experiences of the learners. Company X illustrated this, where they provide engineers with prior CAD skills, a tailored 3-day training course instead of a standard 4-day training course. Even though their engineers previously known CAD system was different, the basic functionality and logic of the CAD software was similar. The andragogy approach was experienced at Company X where engineers in the Engineering Department have shared responsibility for their learning and self-development. For example, engineers can request their own advanced CAD training when they feel competent with their basic CAD skills. However, these self-directed engineers have to allocate a convenient time to attend an advanced course that fits around their work schedule. The standard CAD learning modes are described in section 4.2.1.

In contrast to the andragogy approach, academic environments tend to follow the pedagogy instructional approach. This was demonstrated at WMG where the tutors decide what the students have to learn and provide the same generic knowledge-based content to all students. However, streaming students had been partially introduced at WMG, as students with technical backgrounds were encouraged to take more business related module lessons, and visa versa. Nevertheless, the content level was not streamed, and students with some business or technical knowledge had to sit through all the lectures, even the initial introductory lessons. Additionally, the author's MSc project students said that they chose their optional modules based on the likelihood of obtaining good grades, in order to achieve a good MSc degree. This is a dilemma for any academic establishment providing qualifications. Perhaps mature students, as the author explained in the Personal Profile submission (James-Gordon, 2004b), choose modules in which they feel less able, in order to provide them with the necessary competencies, but there is no guarantee.

However, companies are now requiring customised education for their employees to meet their company's specific requirements, as reported in submission 5. A dedicated MSc programme was developed by WMG together with Marconi Communications and was termed the 'Marconi Masters'. Here, many of the module lessons were tailored to Marconi's requirements and their employees' ability, with appropriate use made of blending the e-learning activities with the instructor-led lessons, such as having Web-based syndicate work. This specific programme minimised the time learners were away from Marconi, as only the necessary knowledge for the task was learnt. Hence, WMG had provided both types of learning approaches by having 'specific' post-graduate company MSc programmes, as well as 'general' post-graduate MSc programmes, as introduced in section 3.3.1. Consequently, there were e-learning activities in the modules that had adopted a more learner-oriented approach. For example, there were problem-solving tasks allocated in the syndicate group exercises, and the authority given to the students to populate virtual libraries with relevant information and links. Hence the andragogy approach was demonstrated, by the students taking responsibility for these types of learning activities and being allowed to share their knowledge within the group. Additionally, the PMA work of both the 'specific' company MSc and the 'general' MSc demonstrated the students' ability to be self-directed in investigating relevant information for their assignment. Both the pedagogy and andragogy approaches are necessary in engineering learning environments, as they help provide the underlying learning process from novice to expert, with responsibility from instructor-led to learner-oriented as represented by the learning modes in section 4.2.1. Andragogy also has similarities to experiential learning which is described in the next sub-section.

4.1.1.2 Experiential Learning

'Experiential learning' is where individuals actively engage in experiences where they can make discoveries and experiment with knowledge themselves instead of reading or listening about experiences of others. Thus, learning is by doing, and can apply to any kind of learning through experience. Individuals reflect on their experiences, and so develop new skills, new attitudes and new ways of thinking (Kraft & Sakofs, 1985). Individuals can also relate their existing knowledge and prior experiences to the current experience in order to improve or adjust their understanding. Kolb's (1984) work in experiential learning is one of the most cited and well-known, and was researched and written up in submissions 1 and 4. Yet, Kolb drew upon and integrated contributions of other educationalist such as:

- John Dewey (1938), who emphasised the need for learning to be grounded in experience. Central to Dewey's philosophy is the notion that learning is a lifelong process which happens in all of the individual's experiences, and not only in his or her instructor-led classes. Dewey's work is often referenced in tracing the history of experiential learning. It highlights the emergence of a learner-oriented approach where discovery through experience leads to the individual becoming competent.
- Jean Piaget (1970), who described intelligence as the result of an individual's interaction with the environment. Piaget studied stages in children's learning development and reasoning processes, which led Piaget to explore individual knowledge and experience. Piaget identified the learning process as a balance between accommodating concepts to experience and assimilating experience into concepts. For example, an individual draws knowledge from the environment and learns to assimilate it under concepts of knowledge related to his or her experience.
- Kurt Lewin (1951), who was concerned with the combination of theory and practice, and the importance of people being active in learning. Lewin discovered that learners retained 75% of the learning content when involved in 'learning by doing' activities, 90% when teaching others the content, and 5-10% retention rates when reading or attending lectures. Lewin also coined the term 'action research' as described in section 2.2.1.

In industry, engineers predominantly learn 'learn by doing', as demonstrated by the Company X case study. After the training courses at Company X, such as the CAD courses, engineers 'learnt on the job' in order to increase their competency. This is emphasised by Senge (1992) as being that *"the most powerful learning comes from direct experience"*. Engineers' skills improve the more they utilise the CAD tools, and they still produce useful design work whilst learning. However, extra time is initially given to newly trained engineers at Company X to allow for their learning and familiarisation with the CAD's functionality and its graphical user interface. Additionally, engineers increased their engineering knowledge, capability and experiences by using the CAD software to design and model components. This is because engineering considerations, such as Design-For-Manufacture (DFM), Design-For-Assembly (DFA), material selection, FEA, and geometric tolerances are continually reviewed throughout the product-development process.

Experiential learning is similar to andragogy because it takes into account the individuals' different existing levels of knowledge and prior experiences, as well as encouraging a self-directed learning approach. However, the author discovered that experiential learning also encompasses feelings, behaviours and emotional components of learning. The experiential working of engineers combines not only their experiences, but also their perception, cognition and behaviour. Therefore, applying experiential learning principles to the design of e-learning content facilitates the following for learners:

- Self-directed learning processes and direction.
- Clear learning requirements and instructional objectives defined.
- Well-organised learning activities.
- Positive attitude and environment for learning.
- Ability to assess progress and achievements.

Learning experiences and assessments, as well as having the appropriate content being taught, are important aspects within experiential learning activities for engineers. However, the traditional focus of learning has tended to be on providing 'quality content' (Oliver et al, 2001), rather than providing 'quality learning experience' or 'quality learning assessment'. The framework in figure 3-1 illustrates these areas as G and H, which illustrates how the philosophy factors are integrated with other factors in the delivery and management categories respectively to achieve these qualities. Additionally, having 'real' learning situations can help provide a balanced combination between content, experience and assessment. This can be achieved by having learning activities that incorporate case studies and syndicate tasks in academia with peer-assessments, or by having work-based exercises that follow on from the training exercises in industry with self-assessments.

The next sub-section discusses the learning theories, which have similar related issues with the approaches already discussed in this section with regard to learning responsibility, i.e. dependent or independent learning. Section 4.1.3 also discusses experiential learning as being cyclic and being able to structure learning sequences that relate to respective learning styles of engineers.

4.1.1.3 Learning Theories: Constructivism & Objectivism

The main investigation into learning theories was reported in submission 2, where key underlying methodologies for designing e-learning content were identified. These ranged from the programmed instruction of the objectivism theory to the discovery learning of the constructivism theory. This sub-section discusses these two opposing learning theories and their value and relationship to engineers, and examples of practical applications are given.

There were many different learning theories investigated that provide a basis for designing instruction. Both 'objectivism' and 'constructivism' have been two of the main groups of theories explored by the author, which have been incorporated into the framework's development to provide guidance for instructional practice and creating effective learning content for engineers. These learning theories and their assumptions can be mapped onto practical approaches, and so a brief explanation of each theory is outlined next, before discussing specific issues.

With the 'objectivism' theory, the assumption is that behaviour is a function of its consequences and learning is achieved through response and immediate reinforcement (Khan 2001; Wild & Quinn, 1998). The underlying model for objectivism is 'behavioural psychology', where psychology is based on observable behaviour, which is determined by outcomes or consequences (Skinner, 1974, cited in Phillips, 1997). Performance is seen as a useful outcome of learning behaviour. The practical approaches researched for designing learning content using the objectivism theory are as follows:

- Tasks that break down behaviour into a sequence of actions that can be monitored.
- Assessment exercises that measure if the instructional objectives have been fulfilled and if behaviour has changed against the performance criteria.
- Support for learner's progress and pace.

The instructors researched have predominantly shown to adopt an objectivism theory with initial lessons, where individuals are presented with information which they replicate in exercises or repeat back to the instructor in some form. Thus learning is by acquisition. This was observed in the introductory classes of the academic and the industrial case studies. There are comparisons here to the pedagogy approach, with similarities in their concepts regarding dependent learning. Objectivism uses resulting behaviours, which can be modified by the consequences of rewards and punishments. This was illustrated in the presentation, demonstration and guided learning modes of Company X's CAD training with engineers practising and repeating step-by-step exercises, as described in section 4.2.1. However, the self-directed and problem-solving learning modes encouraged the engineers to apply their newly acquired CAD knowledge to perform multi-solution exercises and 'real' work-based problems. Hence, the engineers on CAD training courses at Company X were seen to progress through from the objectivism to the constructivism learning theory.

With the 'constructivism' theory, the assumption is that information is interpreted and learning evolves under the control of the individual (Khan 2001; Wild & Quinn, 1998). The underlying model for constructivism is 'cognitive psychology', where information utilised by the learner can be interpreted differently, as well as applied differently to create his or her own knowledge. Therefore, cognition needs to be understood in terms of the situation, purposes, tools and tasks in which the knowledge is to be learnt. Knowledge is utilised in context to solve a problem and can develop by application with the individual or by interaction with peers and instructors. The practical approaches researched for designing learning content using the constructivism theory are as follows:

- Activities that are self-directed, learner-oriented, as well as provide some collaborative learning tasks.
- Assessment exercises designed around 'real' problems, which encourage self-evaluation that increases the learner's responsibility.
- A goal-based structure developed through the interaction between the instructor and learner.

Constructivism can be seen to have comparisons to the andragogy approach regarding independent learning, where self-directed engineers are knowledge-searching individuals that transform and interpret experience using their developed mental structures. Thus learning is by participation. The author agrees with the statement made by Ryan and his co-authors (2000), which describes the learner as *"not a passive recipient of knowledge but an active participant in* *the process of learning"*. New knowledge is absorbed by producing cognitive structures that are similar to the experiences engaged in (Ryan et al, 2000; Wild & Quinn, 1998). Hence, engineers can adapt themselves to these newly developed knowledge structures and use them within their collection of experiences as they continue to interact and discover meaning within the engineering environment. Constructivism builds on Schon's (1983) concept of the 'reflective practitioner', as engineers encountering a problem, draw on previous experiences and go through various solutions until the problem is resolved. By evaluating and reflecting, engineers enhance their learning as well as add to their collection of experiences.

However, the discovery learning of the constructivism theory does assume that individuals have research and exploratory skills, which they may not adequately have. Therefore, appropriate technologies need to be considered to assist discovery learning activities, such as functional user interfaces and adequate support tools. Combining the programmed instruction of the objectivism theory can also be used to guide and manage the learning experiences for the individual. Hence, the research established that an effective solution is to have a learning environment that guides and manages discovery learning, by incorporating the appropriate parts of both constructivism and objectivism learning theories. Yet this balance is likely to be different for each learning application and individual learner. The individual can then have control in discovering knowledge with multiple opportunities to create, organise and structure information, and contribute to his or her own resources and experiences. The tutor (human or computer) can then provide the guidance, support and feedback to the individual. Boundaries can be defined to clearly explain learning objectives, assessments and practice, with specific timeframes and deadlines set. The learning objectives can also define expected user performance. Assessments can capture these metrics as well as measure user understanding, with relevant practice for the required knowledge or skills from tutorials or 'drill and practice' exercises. Therefore, the development and delivery of learning content and the associated learning activities can incorporate the guided-discovery learning approach in activities. These activities can comprise of self-assessments with peer and instructor-led assessments, synchronous with asynchronous communications, and online help facilities with interactive computer-based tutorials.

In the research, the objectivism theory emphasised the importance of presentation of the learning content and replication by the learners. Individuals are described as information-receivers, and tutors as the information-givers. Research into constructivism emphasised more of the interpretation and creation of knowledge. As individuals become self-directed learners, the role of tutor changes to more of a coach, assisting learners to process their own discovery of knowledge. Even though Company X have self-directed engineers, their current e-learning environment is an information-based system with limited discovery learning activities available for these engineers. In contrast, Cisco Systems developed a LMS with the capabilities of personalising the learning content to meet the individual's requirements, as described in section 4.4. Therefore e-learning providers such as Instructional Developers, Module Tutors and Industrial Trainers, need to combine these key issues to provide engaging, self-directed and guided learning content.

There has been a certain amount of overlap between learning theories and other instructional principles researched, but submissions 1 and 4 detailed the main factors for designing e-learning content, taking into consideration these different philosophies. The instructional principles need to remain flexible, as the design of e-learning content can draw on many theoretical learning approaches. Yet, many professional Instructional Developers, as researched by the author and reinforced by Khan (2001), align e-learning content to only one of these approaches. The research reported in submission 2 that engineers need to utilise a combination of learning theories and have a range of learning approaches, which provides the required guided discovery learning experiences suitable for them. However, the amount of guidance and support can differ for each engineer depending on his or her degree of motivation and interaction received, as well as his or her existing knowledge and skills.

Building appropriate instructional principles into e-learning activities can help learners in the engineering environment to engage, participate, persevere and become satisfied with their capabilities. Confidence can also grow as individuals complete each lesson and progress to the next, acquiring new knowledge or skills that can be used on required tasks, or retained and applied to future tasks. Steed (1999) divides these into three main areas – behaviour change, information processing and motivation, and these are summarised as:

- **Behaviour change:** Objectivists believe that behaviour is caused by learning experiences which involve practice, observation, reproduction, guidance, feedback and/or reinforcement.
- **Information processing:** Constructivists believe that information is more likely to be acquired, retained and retrieved for future use if it is learner-discovered, relevant and builds on existing knowledge.
- **Motivation:** Humanistic psychologists believe the way that people feel about a task affects their commitment to it. Empowered learners are likely to accept and undertake challenges and changes, whereas anxious learners are likely to resist these, such as adopting new e-learning methods. Motivation issues are further discussed with the 'affective' learning domain in the next section.

4.1.2 Learning Domains

Learning domains represent the different motivational, knowledge, understanding and communication levels experienced by learners, and these were fully reported in submission 4. The research identified 'motivation' as an important area to initiate and maintain the engagement of the learning process for individuals such as engineers, and so the main issues surrounding motivation are outlined in this section.

The motivation of engineers to undertake any learning activity is dependent on the way they feel and their commitment to the activity. If they feel threatened, anxious or have low esteem, they are likely to resist any change such as the introduction of new e-learning methods. Steed (1999) suggests that confident and empowered learners are more likely to accept and undertake new challenges, and be active participants and collaborate in the learning environment. Keller (1983, cited in Steed, 1999) developed the 'affective' learning model, referred to as ARCS (Attention, Relevance, Confidence, Satisfaction), to describe the way of understanding the motivational needs of a learner. The ARCS model describes these four features within the learning domain factor (Steed, 1999), which connect to other factors in the framework:

1) **Attention:** Engaging and maintaining the learner's attention can be achieved by the design of the user interface and its usability, as will be discussed in the framework's delivery category in section 4.2. This can incorporate the appropriate use of navigation structures, links, readability features and multimedia techniques. The sequence of instruction needs to be consistent, logical and well organised in manageable e-learning chunks, referred to as 'learning objects', as will be described in section 4.2.4. These not only deliver bite-sized content to individuals with limited time for learning, but those with short concentration spans can benefit. Hence, the research established that modular learning content can help to improve retention and recall of the content, as well as be engaging.

2) **Relevance:** After achieving the learner's attention, the content needs to relate to the instructional objectives and the learner's current task, as well as to the learner's own self-development objectives. The learning environment can be customised to the learner's profile where possible, to suit different learning styles, needs, existing knowledge and skills, and prior experiences. Quality learning experiences consist of having access to a variety of rich, relevant information sources, together with having appropriate support when required. An instructor, whether human or an automated

online assistant, can provide this support, guidance or feedback to the learner. Additionally, the learning environment needs to contain clearly defined instructional objectives with expected learner performance, assessments to measure performance and understanding, and relevant practice of the required knowledge or skills. Support with learning activities is discussed in section 4.3.3.

3) **Confidence:** This begins with the learner being aware of the performance criteria with different achievement levels. The learner's confidence can increase by having opportunities to demonstrate his or her newly acquired knowledge or skills in a non-threatening environment, and by having adequate feedback and collaboration with peers. The author experienced this increase in confidence with the CAD trainees as they progressed through the learning modes, from their step-by-step guided exercises to work-based problem-solving exercises. This is further discussed in section 4.2.1. However, CAD support was given by the instructor during the class as and when required. Learners often increase their confidence by having control of their own discovery of knowledge and by having multiple opportunities to create, organise and structure information into context, as well as build on their prior experiences. This was demonstrated in the case studies. Yet, learners need to be confident in controlling their own learning pace and sequence, and be able to achieve important set learning milestones critical for themselves as well as for their organisation. Self-directed discovery learning, as emphasised throughout the research, therefore requires appropriate direction and guidance.

4) **Satisfaction:** One of the learner's main feelings of satisfaction comes with successfully completing an exercise or assessment. This was experienced with the trainees after the CAD exercises at Company X. Having appropriate assessments with positive, responsive and individual feedback provides a level of satisfaction to the learner in their own ability to learn and perform. Additionally, self-assessments are

important during and after the learning activities. A satisfied learner, confident in his or her own proven ability, as Steed (1999) points out, is more likely to accept and apply newly acquired knowledge.

The sense of achievement often motivates learners to continue with further learning activities. Each of the latter four stages builds from its previous stage. For example, relevance is sought once attention has been achieved, with finally satisfaction being achieved from successfully accomplishing the learning activity. The relevance of the learning content to the learner, as described in point (2), can be strengthened if the learning environment is customised to the learner's profile. This can be achieved by taking into account the individual's learning style preferences, which are described next.

4.1.3 Learning Styles

The different approaches or ways of learning describe the learning styles. A number of people have tried to categorise the types of learning styles in detail, but Kolb, a professor in organisational behaviour, is one of the best known. Kolb (1984) built on work from others, such as Dewey (1938), Lewin (1951) and Piaget (1970) as discussed in section 4.1.1.2. Kolb identified four distinct learning stages on a continuum running from concrete experiences, reflective observation, abstract conceptualisation and experimentation. These also provide a four-stage learning cycle, which is fundamental to Kolb's experiential learning theory as discussed in section 4.1.1.2. These stages can be related to the learning cycle of the engineering development environments studied by association to the respective learning styles as reported in submission 1. Honey & Mumford (1992) developed a learning style system as a variation on Kolb's work with four key learning styles as being activist, reflector, theorist and pragmatist. These also represent stages in the learning cycle and mutually correspond to Kolb's learning cycle and can be overlaid. These are illustrated in figure 4-1 with an engineering product-development example as defined for Company X, as follows:

- **Concrete experiences:** Iterative simulations are run, such as Finite Element Analysis (FEA) on a CAD model, to see where the high areas of stresses are, in order to prove the feasibility of the design. This is an 'activist' learning style where learning is achieved by doing and experiencing.
- **Reflective observation:** Analyse the output FEA results and the probable design effects. This is a 'reflector' learning style where information is gathered before conclusions are reached.
- **Formulation of abstract concepts:** Use the CAD software to develop a new part or modify the existing part, based on the prior FEA results. This is a 'theorist' learning style where the reason behind things, concepts and relationships are necessary for understanding.
- **Test concepts on new situations:** Examine the newly modelled CAD part in a CAD assembly, to see if this part fits with other parts and that there is adequate clearance. This is a 'pragmatist' learning style by testing the practical application of what has been learnt.

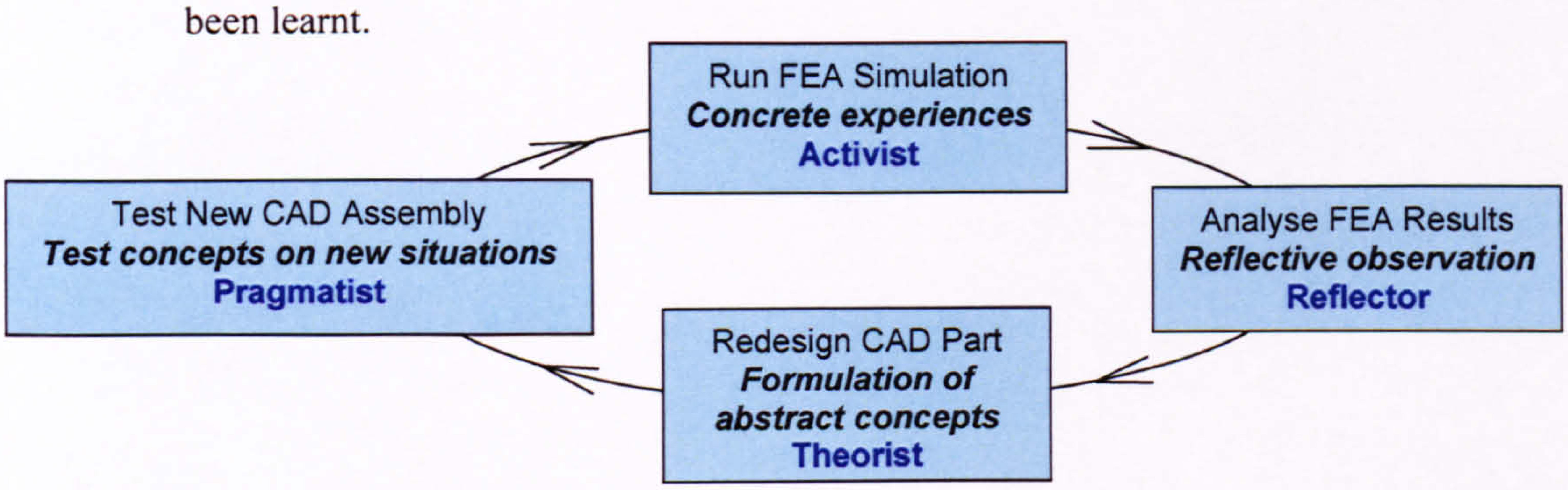


Figure 4-1: Learning Styles in the Engineering Design & Development Cycle (adapted from Kolb, 1984; and Honey & Mumford, 1992)

This continuous learning cycle is typical of the engineering design and development process in industry, and engineers in these environments practise all of these learning styles at different stages of the product-development. Hence, the Honey & Mumford's questionnaire survey at Company X, as described in section 2.2.3, found there was an even distribution of engineers against these learning styles tested. The author experienced, and continued to observe this learning cycle at Company X during her research. When optimising a product-development each learning style is adopted and the engineer's own self-development increases. Each learning stage outputs data, which in context is used as information required for the next stage's input. Deming's continuous improvement PDSA cycle (1993) has similarities with Kolb's learning cycle (1984) and Honey & Mumford's corresponding learning styles (1992), as listed below:

1) **Plan:** Establish a plan for improvement.

2) **Do:** Test the plan.

3) **Study:** Analyse, reflect and evaluate what has been done.

4) **Act:** Learn and change from experiences.

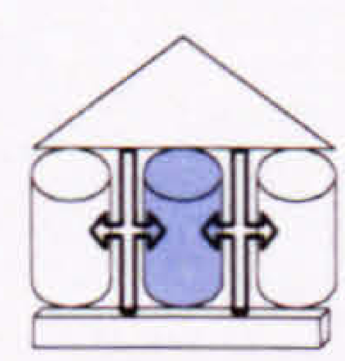
Deming had originally called step (3) 'check', but changed it to 'study' to emphasise experiential learning (Deming, 1993). Thus, the continuous improvement cycle relates to experiential learning because previous experiences are taken into account from each cycle as discussed in section 4.1.1.2, which corresponds to Kolb's model. Both product-development and self-development are continuous improvement processes, because every time the cycle is completely iterated not only does the product improve, but also the engineer's experience is reinforced and increased.

A further survey was carried out at Company X to identify other learning styles using a questionnaire developed by Felder (1996). This was because the author believed that Felder's questionnaire provided a more balanced approach by pairing learning styles, as described in section 2.2.3 and reported in submission 1. The evidence from this showed that engineers in the design and development environment at Company X, i.e. in the Engineering Department, have a strong 'visual' learning style preference compared to the rest of the professional population. These findings are illustrated in appendix A1. However, it is debatable if engineers are born visual learners or if they develop this learning style preference due to their environment. Regardless of which it is, the consequence is the same, i.e. engineers are visual learners.

Therefore their learning can be more effective incorporating visual techniques, such as diagrams, sketches, photographs, schematics, flow charts, pictures, videos, computer graphics and demonstrations, in educational and training programmes as well as in their everyday working environment. The present CAD training in Company X contains some of these visual techniques and so helps to satisfy the engineers' visual learning style preference. Additionally, CAD can incorporate advanced animation, VR and simulation techniques into its functionality, as well as provide coloured graphics to sketch, model, assemble and analyse three-dimensional (3D) parts. CAD commands can also be represented as meaningful graphical metaphors, i.e. icons, and the screen layout can be customised to suit the engineer's style of working, as well as learning, using a choice of icons and graphic colours

Office software tools, such as Microsoft Word, Excel, Access and Project, and other instructional content that engineers are required to use as part of their daily work at Company X, do incorporate graphical tutorials, presentations and demonstrations. In addition to the presentation of e-learning content, its usability and delivery are important for engaging engineers. The next section discusses the main factors investigated for delivering the e-learning content, and this encompasses the user interface design and its usability issues, which can affect the motivation of learners.

4.2 Delivery Category



This section highlights the important factors researched in the delivery category of the framework, and incorporates the user interface with its usability issues affecting an e-learning development. The main usability areas researched cover the navigation structures, readability issues and different multimedia applications. The role of the delivery function is to integrate the learning activities together in a transparent way, enabling the learner to navigate effortlessly between activities. This involves accessing, using and interpreting the learning content, collaborating on activities involving the content, and having feedback on the knowledge or skills acquired from the content. Thus, the main factors described in this section are learning modes, communication and collaboration techniques, appropriate use of feedback, learning objects, and finally the user interface design and its usability issues.

4.2.1 Learning Modes

Learning modes help to build an experiential environment that goes beyond 'drill and practice' activities, and is capable of producing realistic problem-solving situations, such as with VR or simulations (Steed, 1999). The learning modes were researched and reported in submission 4, but due to their importance in the engineer's learning process, the main issues are explained in this section using the Company X case study to illustrate the various modes.

Engineers in their environments experience different learning modes ranging from presentation, demonstration, guided and self-directed through to problem-solving activities, to suit their level of competence or expertise. The CAD training and learning environment at Company X is represented through the following learning mode stages:

1) **Presentation:** Engineers are presented with new CAD information and taught the basic CAD concepts, theory and functionality.
2) **Demonstration:** Engineers are shown how these CAD concepts relate to the current learning activities and then they are required to complete a small task after each demonstration.
3) **Guided:** The engineers are supported and monitored during their step-by-step CAD exercises, which group together a series of tasks learnt from the demonstration stage.
4) **Self-directed:** Engineers consolidate what they have learnt so far and control the sequence and pace of an exercise that can have different paths to the solution, such as for command selection and graphical feature construction. The engineers follow the

same engineering drawing to achieve the required and identical 3D CAD model (part or assembly) for the exercise.

5) **Problem-solving:** Engineers are presented with a relevant work-based design problem to solve using the CAD system. This discovery learning process encourages the use of their newly acquired skills to solve an actual design problem. Again there are different paths for constructing the 3D CAD model, but this time the models can look very different, even given the same design requirements. This is typical in engineering development. If a design specification is given to two engineers, the designs will differ depending on the engineers' knowledge, CAD skills and prior engineering experiences, but the 'fit and function' of both designs will be the same.

At Company X, the presentation and demonstration learning modes are currently instructor-led for the CAD training. This was typical of other engineering organisations experienced by the author, with the CAD information being initially presented to the observing engineers. Then during these instructor-led modes, the CAD tasks involve engineers practising and repeating demonstration activities. The guided mode assists in building the engineers' confidence by having support available when required during the CAD exercises as discussed in section 4.2.1. Also the instructor needs to express that making a mistake, i.e. 'trial and error' is part of this learning process. The self-directed mode encourages engineers to apply their newly acquired knowledge more than in the guided mode, and perform interactive tasks on their own and have control of their own learning sequence, pace and style.

The learning modes relate to their progression from the objectivism to constructivism learning theories as described in section 4.1.1.3. The objectivism learning theory is experienced in the presentation, demonstration and guided modes, and the constructivism theory is experienced from self-directed to the problem-solving modes. The problem-solving mode builds from the self-directed mode by presenting the engineer with different learning exercises in different situations, in order to apply their own judgement and practise their newly acquired skills. Eventually engineers become competent and skilled at using CAD as a design tool from utilising it on a daily basis, and also they become more experienced at engineering design. Figure 4-2 illustrates the association between the learning theories in the philosophy category with the learning modes of the delivery category, and the type of assessment required.

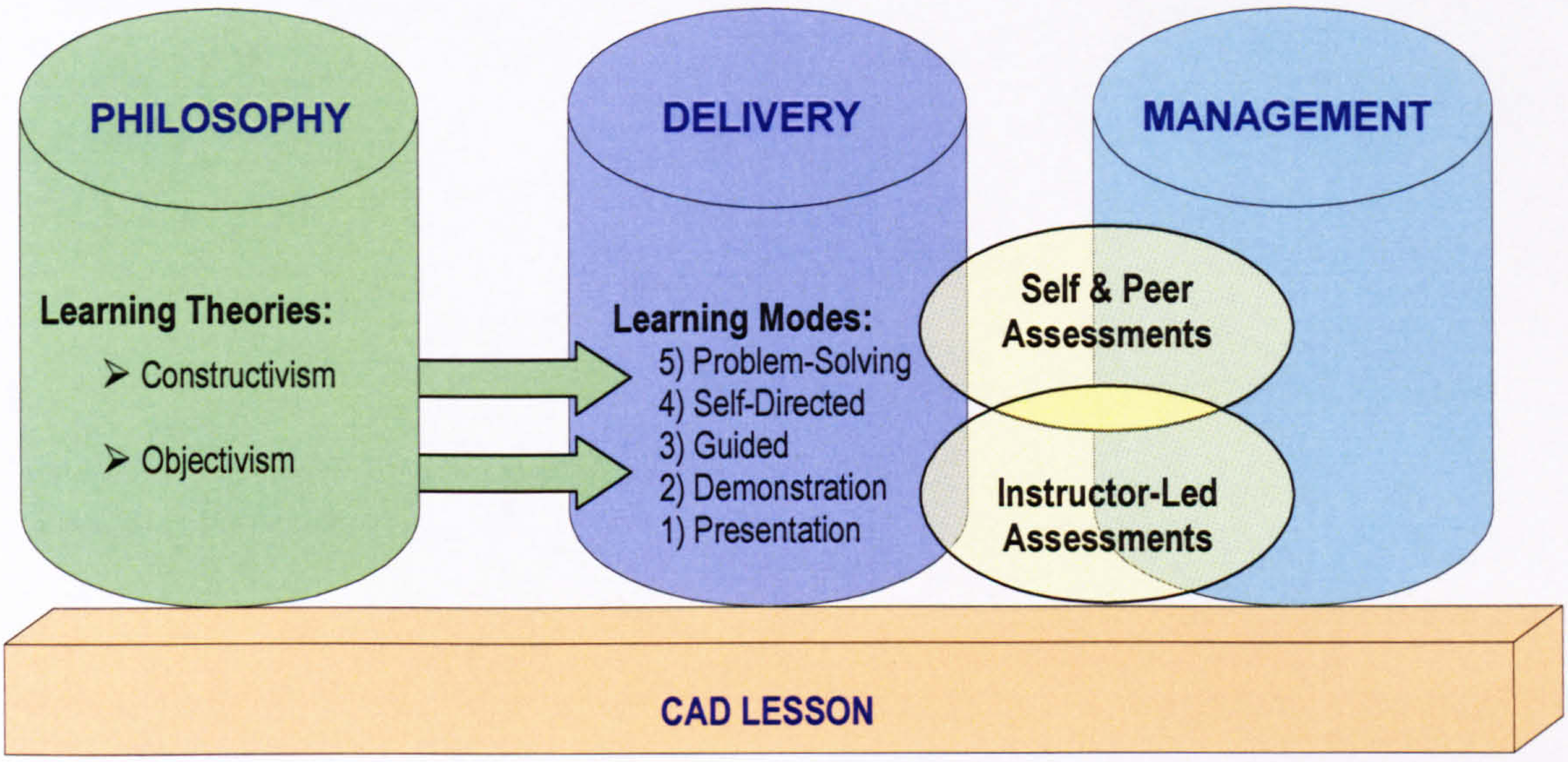


Figure 4-2: Connections between Learning Theories, Modes & Assessments in the Framework

The instructor-led modes often have instructor-led assessments with step-by-step exercises. These assessments can be given to engineers before and after a task in order to determine their levels of competency. From the guided to problem-solving modes, engineers can test themselves by repeating an exercise without viewing the step-by-step instructions, by just examining the required engineering drawing which represents a 3D part or assembly. A follow-up assessment of an engineer's activities can provide feedback and advice, and suggested solutions or alternative routes when a problem is encountered. Peer-assistance can be given in this non-threatening familiar learning environment to test an engineer's knowledge and assumptions about a multi-solution problem for optimising a design. This also emulates the real engineering development environment, and feedback given from peers can help verify and strengthen an engineer's understanding. The next section discusses communication and collaboration techniques with peers.

4.2.2 Communication & Collaboration Techniques

Engineers make extensive use of communication and collaboration techniques through interpersonal means as well as through shared information resources (Hertzum & Pejtersen, 2000). Studies reviewed by King et al (1994) revealed that engineers spend 40-66% of their time in communication and collaboration activities in order to obtain information for their tasks and disseminate the results from their work. Communication is the flow of information, and collaboration uses communication techniques to share information in joint activities (French et al, 1999).

The communication and collaboration functionality within e-learning environments are provided by using asynchronous and synchronous techniques (French et al, 1999; Hall, 1997; Ravet & Layte, 1997). Each technique has its strengths and weaknesses and is appropriate for a different set of learning situations. Asynchronous and synchronous techniques were reported in submission 2. Online synchronous interaction involves learners, or learner and instructor, being online at the same time and communicating in real-time. The main synchronous techniques investigated were:

- **Chat rooms/ Instant messaging:** These provide real-time communications between two or more people based on typed text. WMG trialled chat rooms in their 'Global E-Business' (GEB) module on the E2BM MSc course. This allowed module-specific syndicate groups to jointly share ideas and results instantly. Students were able to discuss their work with the Module Tutor at a set time. However, this was not practical when the module was run for students overseas with the Module Tutor UK-based because of differences in the time-zones. Also, all parties needed to be on-line at the same time, with times needing to be arranged by the tutor in advanced. These restricting features caused this synchronous technique not to be taken further.

- **Virtual whiteboards:** These provide an area on a computer screen where multiple users can write or draw on. Whiteboards were investigated by WMG's Instructional Developers, but presently the Module Tutors do not require them on their E2BM MSc modules. However, Company X uses a virtual whiteboard within their video conferencing technology.
- **Video conferencing:** This provides a real-time online conference facility between two or more participants at different sites using the Internet to transmit digital compressions of audio and video data streams. Participants use a Web-cam, microphone and speakers mounted on their computer to communicate. Besides the audio and visual transmission, video conferencing can be used to share documents, computer-displayed information and whiteboards. Video conferencing can help provide a visual examination of learners to identify their authenticity prior to taking online tests as well as gauge their level of satisfaction. Video conferencing is presently not a practical or cost-effective option for WMG due to initial set up, distribution and ongoing maintenance of the technology, and their lack of resources. Company X had invested in this technology to provide a means for their engineers based in the UK and Asia to work collaboratively together on product-development issues. This helps them to discuss ideas and gauge their colleagues' reaction as well as sketch suggested solutions, without the expense of sending their UK-based product-development team aboard.

The main benefit of synchronous interaction is that the acquisition of information or knowledge and receiving peer or tutor feedback is immediate. However, the downside experienced in the WMG case study were the imposed time constraints, logistics in getting students online at the same time, as well as the technology problems. Also, bandwidth is a consideration when designing content using synchronous techniques, as Steed (1999) points out that its limitation can cause poor media performance and learners experiencing long wait and response times. To avoid bandwidth consuming techniques like video conferencing, individuals can be to represent by avatars, i.e. 3D computer generated models of themselves or an icon (Ravet & Layte, 1997). Asynchronous techniques have been utilised more with WMG's e-learning environment. This is because they have either been incorporated in E-Lab's development tools and so have incurred no direct costs to WMG, or available as standard technology at WMG. Also, asynchronous learning provides the flexibility for learners to be self-directed and control the pace, and often time, of their learning activity. The main asynchronous techniques investigated were:

- **Email (Electronic Mail):** This is one of the main forms of communicating a text-based message from one person to another, or others, via the Internet or Intranet. Messages can also contain attachments, such as text document or picture files. Emailing is used by Company X's engineers and WMG's students as their main method of electronic communication. Often professional engineers email team members and other product-development stakeholders with attached reports or CAD files, prior to any face-to-face collaborative meetings taking place. For example, meetings to discuss product-development feasibility issues, such as DFM and DFA with the Manufacturing Department, or external meetings to discuss prototype built issues with suppliers.

  Initially, a module-dedicated emailing system was developed by the Instructional Developers at WMG for their bespoke platform. This created unique student emailing accounts that were able to be monitored by WMG's e-learning providers. Emailing communications were only available between the students on a particular module and the Module Tutor. This email system was eventually stopped due to the following main limitations identified in the WMG case study:

  - Considerable time was needed by the Instructional Developer to create the students' email accounts and input their unique login and initial password.

- The students' details were not transferable to another E2BM module, so their details had to be entered again.
- The email account was only active during the module running and the associated PMA work, i.e. seven weeks.
- The email accounts were not able to be integrated with the students' main university email accounts, in order them to retrieve old module-based emails.

- **Discussion Forums/ Bulletin Board:** These services provide areas where individuals with common interests can exchange open text-based messages as threaded discussions, and links to webpages to support the message. The individual has control over posting to and browsing the boards. Presently, the GEB module on the E2BM MSc course uses discussion forums as a mid-module activity. Individually students post their associated working activities and outputs from a syndicate group exercise. This provides shared learning resources for all in the group. All the content posted is then assessed by the Module Tutor as a group effort. Company X did not use discussion forums in their working or learning environments.
- **Virtual Library:** This was a bespoke online collaborative learning space created by the Instructional Developers at WMG, which worked like a non-threaded bulletin board. Virtual libraries were produced in the initial e-learning trials at WMG, before E-Lab's development tools were available. They allowed students and the Module Tutor to populate, access, and share useful links and upload relevant information for their learning resources. These comprised of module-specific documents, business case studies, online catalogues, and hyperlinks to websites and appropriate University of Warwick's library literature. The main limitations with the virtual library functionality identified in the WMG case study were:

  - Each virtual library was module dependent, so considerable time and effort was spent by Instructional Developers setting one up, each time a module ran.

- They required constant monitoring of content by the Module Tutors as there were often repeated links and uploaded entries posted.
- Instructional Developers had to continually modify the virtual library's software code to cater for the former point as well as changes requested by Module Tutors.
- The virtual library was only available during the module running and the associated PMA work, and so the information and links were not accessible afterwards.

Since the initial trials of virtual libraries at WMG, Module Tutors have not required them within their modules. If this functionality is needed again, this can be provided by E-Lab's development tools and incorporated within a discussion forum or group Web-log. Section 4.4 describes Web-logs which have advanced in educational use since submission 2 was reported.

Both asynchronous and synchronous techniques are important for the interactive learning experience for an individual and a group, and so an effective e-learning environment needs to integrate them appropriately. For example, the learner can study and discuss a topic asynchronously, in order to gain a common level of understanding. Then he or she can check their understanding with their peers synchronously in a chat room or a VLE. Alternatively, a self-assessed multiple-choice quiz can be taken by the learner, which provides immediate feedback of the scored results. Learner assessments are further discussed in section 4.3.6. Feedback is an important element in communication and collaboration activities, as it helps learners and instructors to adapt future learning directions. Feedback techniques are described next.

4.2.3 Feedback Techniques

Feedback techniques are important to reinforce and support the content delivered to learners. Learners can be given feedback on their performance from peers and instructors, but also learners can provide feedback on their learning experiences to them. These two different types of feedback are known as 'extrinsic' and 'intrinsic' feedback, respectively. Both are important factors in providing effective e-learning (Ravet & Layte, 1997; Haynes et al, 2004).

Electronic feedback is given to a learner by using communication and collaboration techniques described in section 4.2.2, as well as being provided electronically, such as by an automated assessment system or within a computer-based simulation. At WMG the main extrinsic electronic feedback, given to a student during a module running and associated PMA work, is by:

- Personalised and supportive emails from the Module Tutor and fellow students.
- Online threaded forum discussions to reinforce understanding and test ideas with peers in syndicate groups.
- Results scored from pre-module self-assessments provided automatically given once completed, which contribute to the overall PMA mark.
- PMA mark and comments (often with sample answers) from the Module Tutor are notified by email. There are plans to electronically post these to student's workspace. Presently E-lab's development tools are not integrated with the post-graduate student record system.

Feedback from instructor-led, peer-assisted, or self-directed assessments can incorporate advice with suggested solutions or alternative routes when a learning obstacle is encountered. Feedback from assessments gives learners an *"accurate gauge of their learning progress"* (Steed, 1999). Learner assessments are described in section 4.3.5. Haynes et al (2004) suggest that good feedback needs to be designed to give information on the quality of learners' work and its strengths and weaknesses, and encourage learners to reflect on their work and work towards managing their own learning. This enables self-directed learners, such as Company X's engineers and WMG's post-graduate students, to develop their own self-development learning plans. At Company X, this can be with the assistance of line managers, HR manager, and training instructor. At WMG, this can be with the assistance of academic mentors, project supervisors and Module Tutors. These plans can describe how learners are going to transfer what they have learnt to their next learning activity or current work-based task.

Learners can submit an assessment of their learning experiences to the instructors, which feeds back against their own learning goals and how they believe they have performed. Having intrinsic feedback on how learners feel about a learning activity can improve a subsequent running of the activity: Instructors can modify the content material and Instructional Developers can alter how the content is delivered. Both Company X and WMG provide evaluation forms to students at the end of a taught module, which enables the students to provide feedback on their learning experiences. This demonstrates the 'reaction' level to learning from 'Kirkpatrick's evaluation model' (Kirkpatrick, 1996), and this is further described in section 4.3.6.

Providing feedback to learners in a VLE can be difficult compared to traditional classroom settings, where learners can just raise their hand and ask the instructor for examples or clarification about a topic. When electronic feedback is given, the instructor can not gauge learners' level of satisfaction with the quality of response given, from their expressions or body language. Making use of video conferencing techniques using Web-cam technology can improve viewing and assessing learners' satisfaction. However, investment in this technology is not a practical option for WMG, as described in section 4.2.2. Having positive, responsive, relevant and individual feedback can help towards this satisfaction level, as point (4) in section 4.1.2 described.

Thus, the design and integration of feedback techniques are important in the delivery of the learning content, as these can influence the learning experiences and level of satisfaction of learners. Feedback given at timely intervals within learning activities can help to maintain or increase learners' motivation with the activity. A way to achieve this is to use 'learning objects' to develop more modular activities and these are discussed next.

4.2.4 Learning Objects

The majority of e-learning content is developed for a specific or complete purpose, such as for a whole lesson or an entire course, with little consideration for its re-use (Harris & Shepherd, 1999). This was experienced with the WMG case study. However, learning becomes more digestible when the content is broken down into manageable chunks. Instructional Developers refer to these small content chunks as 'learning objects'. Two ways for putting the amount of content into a single learning object is by:

- **A logical division of the content.** This can depend on the time allocated or allowed, as explained in the timeframes section 4.3.4.
- **The amount of time a learner can maintain concentration.** Gaining and maintaining the learner's attention was explained in section 4.1.2.

E-learning content can be accessed, and more importantly reused on a modular basis when created from learning objects. With regular feedback at the end of each learning object, learners can be motivated to progress by seeing their own learning objects being completed. Traditionally, learning content for a course has been delivered in several one or two-hour intervals called lessons, and these were experienced with WMG's postgraduate modules. Learning objects are much smaller components of learning, often 15 minutes activities (Harris & Shepherd, 1999). From the investigations, the key characteristics of learning objects are:

- **Self-contained:** Each learning object can be accessed independently.

- **Reusable:** A learning object can be used in various contexts for a variety of purposes. For example a module's introductory session at WMG can consist of several different lesson overviews as individual learning objects, which in turn can be used at the start of each respective lesson. The value of a learning object is increased each time it is reused, because this produces cost-savings by avoiding further effort and time on design and development of its subject matter.

- **Combined:** Learning objects can be grouped into larger collections of content, including traditional course structures.

- **Tagged with Meta-data:** Descriptive information is tagged to each learning object, allowing it to be found by a search engine.

- **Communicative:** Learning objects can communicate to a LMS to obtain information about a learner and record their performance information.

- **Customisable:** Courses can be customised using specific learning objects for each individual, department or organisation. Only the necessary learning objects need to be selected and taken for typically a 15 minute lesson, which provides a just-enough and a JIT approach to content customisation. Modular learning objects help personalise the content by permitting the delivery and combination of content at the required competency level of the learner. However, guidance and close monitoring are required to ensure appropriate selection and combination of the learning objects.

- **Interoperable:** The object approach allows organisations to set their own requirements regarding design, development and presentation of the learning objects based on their needs, whilst being able to connect with other learning systems. As researched and reported for submission 2, having reusable learning objects complies with the Sharable Content Object Reference Model (SCORM) industrial standard.

The utilisation of learning objects was one of the recommendations made by the author to Company X and WMG, which was reported in submission 5. By making WMG aware of the characteristics and benefits of learning objects, their e-learning development team have subsequently begun to investigate and test a more modular approach in their content development. However, when designing content for complete e-learning lessons or for reusable learning objects, Instructional Developers need to model the learning content as part of the larger requirement, such as a course or programme, as well as consider the content for a stand-alone activity. These two requirements do not have to conflict, but both need thoughtful planning to be effective. Additionally, care is required in blending appropriate learning objects, so not only to seamlessly connect them together, but to provide the adequate depth required for the learning requirements. Therefore to assist with the planning, clear specifications need to be established with the range of development concerns, such as what technologies are to be used, and similarly, what templates, standards, structural rules and modular level of content are required. Submission 4 reported the investigations into the content development of the learning objects. The important aspects that came out of the research, and emphasised by Longmire et al (2000), identified that the development of learning objects need to have:

- Consistent terminology and language of the subject area.
- Accessible and comprehensible information.
- Non-sequential information across objects, i.e. independent learning objects.
- Appropriate content and language for a wider audience.
- Searchable areas that use keywords.

These points not only assist in the development of learning objects but they also aid the larger development of the user interface and its usability, which are explained next.

4.2.5 User Interface Design & Usability Issues

Designing an e-learning portal and its associate webpages is not a single activity that only involves selecting the most appropriate Web technologies, but involves considering the philosophy and management aspects of e-learning with the delivery environment. These can require different and often conflicting interface designs. The interface needs to cater for philosophy learning factors such as different instructional principles, learning domains and learning styles, as described in section 4.1. Thus, the challenge is to integrate the necessary functionality within one interface to cater for different e-learning activities, such as:

1) Exercises to work through and practise.
2) Collaboration with peers and instructors.
3) Self-directed and instructor-led assessments.
4) Access to a variety of information sources.
5) Guidance and help for a learning activity.

A way to take into account the visual learning style preference of engineers, as discussed in section 4.1.3, is to graphically represent the above activities as metaphors, i.e. icons, on the user interface. Presently, familiar desktop metaphors are used on most computers and consist of a notepad, calculator, filing cabinet and folders. Therefore, the author suggests the following metaphors to represent the links to the learning activities as listed above: Point (1) can be represented by a hand holding a spanner. Point (2) can be represented by a symbol for people. The link for point (3) can be illustrated as a hand holding a pen. Point (4) can be represented as an open book. Point (5) can be shown as a question mark symbol. These metaphors are respectively illustrated in figure 4-3. Whatever icons are chosen to represent the learning activities, it is important that they remain consistent in their design and functionality, so as to avoid confusion with the learners.

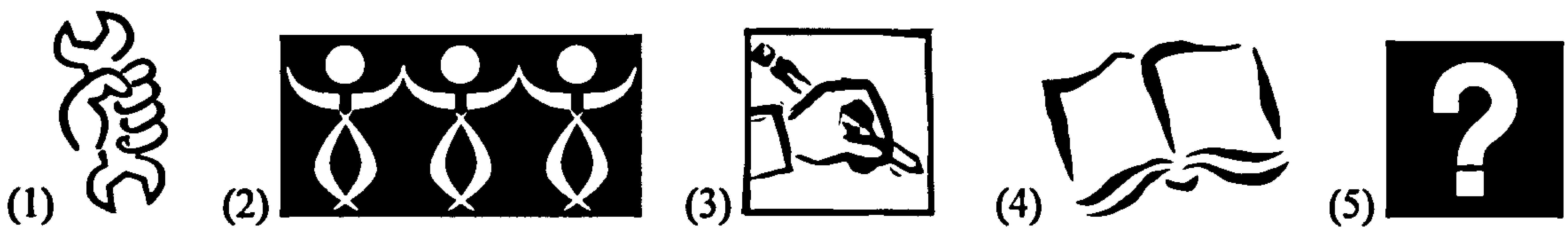


Figure 4-3: Metaphors representing Learning Activity Links.

Maintaining the design consistency with metaphors, which affect the e-learning user interface design, have similar issues to other website designs. Other usability issues that have been researched (Harris & Shepherd, 1999; Spool et al, 1999) and suggested to WMG and Company X, and partially adopted at WMG are:

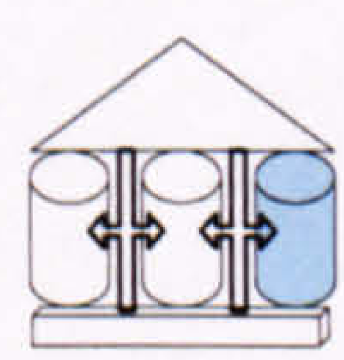
- **Navigation structure:** The hierarchy of menus and content need to be considered with respect to navigation links. Such links utilised at WMG provided the movement up and down long webpages, forwards and backwards between webpages in sequence and between hierarchical linked levels as well as for selecting activities. Links were via menus, metaphors, text or graphics. The placements of these navigation links are important, and care needs to be given for dependencies not to be created between learning objects. The latter was not applicable at WMG as learning objects had not been implemented.

- **Readability features:** Colours, fonts, metaphors and text size can be chosen to assist the readability of webpages. Instructional Developers at WMG spent considerable time liaising with the Module Tutors to perfect this: The actual layout of the text and graphics required design, development and testing time to provide effective readability and 'scanability', i.e. skim reading, of the learning content. This consisted of sections broken down into logical areas, white-space between the blocks of text, bullet points and numbered lists. Each webpage had a meaningful title, with important information written clearly and concisely, and placed near the top of the webpage. Scrolling and graphics were used appropriately, but sparingly, as too much use of graphics can distract learners and is discussed in the next point.

- **Multimedia application:** Appropriate use of multimedia, especially audio and visual, is important. Multimedia needs to enhance the learning experience but not distract the learners. The author observed that there was too much multimedia used with one of the pilot trials at WMG: An electronic introductory lesson was given to students where the Module Tutor's head was moving about excessively, the text scrolled too quickly down the screen, and the narrative audio did not synchronise with the tutor's lip movements. The Instructional Developers realised that by having a still picture of the Module Tutor with the scrolling text and audio was less distracting for the learners.

The usability of an e-learning environment depends on what is attempting to be accomplished. Whether the users are browsing, searching or downloading files, reading instructions for learning activities or collaborating with peers, the main purpose is to obtain information, and in context this becomes knowledge for the user. The term 'user' indicates instructors as well as learners. This is because instructors, as with WMG or Company X, also have to work in the learning environment to develop the instruction or information with the assistance of Instructional Developers. The responsibilities of these different users, i.e. the stakeholders of e-learning, were discussed in section 3.2. The management aspects of e-learning also need to be considered when designing the user interface, and the next section describes how user security, resources, support and administration factors are managed in the learning environment.

4.3 Management Category



This section describes the main factors investigated in the management category of the e-learning framework, which comprise of security issues, instructor and learner resources and support, and administration facilities. However, all factors in the management category have some administration element attached to them, whether this is recording, tracking or assessing student learning progress and achievements, or document managing. For instance, learner participation and achievement in activities can be tracked and recorded. These management activities are not only beneficial for instructors and Instructional Developers, but also for self-directed engineers to monitor their own performance and progress. An e-learning lesson or a complete programme can consider managing factors such as the environment's security, available resources, allocated timescales, support facilities and learners' assessments. These are explained in the following sub-sections. First security features such as access control and intellectual property protection are described next.

4.3.1 Security for E-learning Activities

Security is an important area associated with e-learning which needs to be properly managed to ensure correct authorised use and protection of the e-learning content. Security is especially important for e-learning content that is to be assessed and for corporate e-training involving company sensitive information, as well as for payment over the Internet for an e-lesson. The following are the main issues related to e-learning security that were investigated (Hall, 1997; Steed, 1999; French et al, 1999; Young et al, 1999) and reported in submission 2:

- **Access control:** Managing and authorising different access rights are necessary for different users in the e-learning environment. Students need to access their own e-learning workspace, allocated activities and own work. E-learning providers, such as Instructional Developers and Module Tutors, need to access their e-learning development workspace to create, add, modify or delete learning activities. Thus, authentication is important for an e-learning environment. Authenticating a user can range from entering passwords to using biometrics. Questions can be posed in the middle of a test which asks information on family history that only the authentic user knows. A visual examination of the learner taking the test using video conferencing techniques is a solution, but often not a practical or cost-effective one if many need to be tested, because of the initial set up, maintenance and management issues. Due to the low cost of implementation, passwords are generally used in e-learning environments. At WMG each student and e-learning provider can access his or her workspace from a single entry point using a unique university username and a randomly assigned password. The password can be changed remotely once in the e-learning environment. Once logged on, the student accesses his or her own core and elective modules and any pre-work allocated by the Module Tutor. Initially, separate access was required to each individual module when external e-learning platforms were being trialled at WMG.

- **Information confidentiality:** Encryption can be used to ensure information passing through the Internet remains private. It does this by basically scrambling the information from the sender and unscrambling the information for the receiver only. At WMG, this is particularly important for the e-learning providers delivering the e-learning content or grades to the students, and for students submitting their work or assessments over the Web to the Module Tutors.

- **Protection of Intellectual Property:** Digital watermarking technology can be used to mark electronic text, images and sounds for copyright purposes, so that unauthorised copying can be recognised. Plagiarism software is used by WMG, where students can check their work, make appropriate changes and add citations before submitting their work. Module Tutors can use the software to verify the students' electronic assessments are their own work.

- **Preventing Viruses:** Viruses range from displaying unwanted messages to corrupting files and even the hard drive. They can be attached to files that the user downloads, as well as to Emails. Thus, virus prevention software needs to be installed to protect the e-learning environment. These virus checkers monitor the user's computer system for suspicious activities and known viruses. WMG uses the university's imposed virus protection devices such as firewalls and spam filters.

Having a secure e-learning environment helps to provide a private environment to learn in, trust in the learning content and confidence in using the environment. Managing security is an important CSF and point (12) in section 5.2 identifies this. Managing upstream and downstream resources also require secure access and information confidentially when sending documents. Resources in e-learning activities are described next.

4.3.2 Resources for E-learning Activities

An important issue observed within the case studies, which often gets neglected, is the need for learners to construct reports and presentations to support their learning assessments and progress. Presentation applications are sometimes isolated, and this was highlighted by the students at WMG, as they often found difficulty in combining their learning with documenting their progress. The requirement is to integrate information flow upstream as well as downstream (Ravet & Layte, 1997). Upstream resources are inputs such as reference material, videos and technical documentation, and downstream resources are the outputs such as reports, spreadsheets and electronic presentations. Communication and collaboration with peers and tutors, as described in section 4.2.2, are important as they provide integration between upstream and downstream resources by incorporating shared information and sending documents. The resources provide the link between information sources that contribution to the learning process. Electronic resources trialled by WMG were:

- Learning content accessed through a table of contents, index or glossary.
- References explained or highlighted, if selected or hovered-over with the computer mouse.
- Online communication and collaboration with peers or tutors to share information.
- Information exported to other resources, such as word processors in order to create presentations and reports.

The Internet provides a good media for providing and integrating the above resources. The design and usability of the user interface can be challenging as explained in section 4.2.5, and so providing support with learning activity resources is important, and this is described next.

4.3.3 Support with E-learning Activities

The support facility provides the learner with the direction, guidance and feedback necessary to perform the relevant activities in order to be competent with the task. The different learning modes, as described in section 4.2.1, require different amounts of support. During the presentation, demonstration and guided modes, support is expected, but at the self-directed and problem-solving modes, support can be requested when required.

An e-learning programme needs to incorporate adequate supporting information to assist learners through the learning process. One method of guidance, recommended by the author to Company X as well as to WMG, is to use a 'site map' to describe the different learning activities and how they relate to each other, as well as assist with navigating around the website. The following points were identified from the investigations, predominantly from the case study work, as needing to be considered when designing support features in an e-learning programme:

- A site map that illustrates the sequence of e-learning activities and how they relate to the learning objectives.
- Further explanations and online references made available in an e-learning activity when required. Different learning modes can be developed with different support facilities.
- Visual cues can provide effective navigation for an e-learning activity for engineers.
- Instructional objectives need to be clear and precise, so that learners can tell at a glance what is expected of them and how the objectives relate to their needs.

- A menu can provide choice between the different support activities, such as online help, documentation, self-assessment, practising new skills, writing a report or using a discussion forum to post a description of the problem to request peer assistance.
- Electronic communications and supportive feedback from peers and instructors.

Each learner action and achievement can be recorded and tracked to assist e-learning providers develop improved or bespoke support features in the e-learning activities. Recording and tracking can help learners monitor their own progress and identify areas where they need support. Deciding when support is given in the learning activity can be a decision for the learners, instructor, or both parties, which can be timely intervals in the activity. The next section discusses timeframes.

4.3.4 Learning Timeframes

Learners can have specific time constraints placed on them to complete an activity, by the instructional objectives, instructors, managers, or self-imposed by themselves to satisfy their own learning requirements. In industry, the learning constraints are due to working tasks taking priority and time needs to be found for learning activities to fit around work tasks (Fink & Holifield, 2004). Yet, self-directed individuals, such as engineers, can often set their own learning and working pace, direction and amount they wish to pursue, providing they meet the timeframe requirements, such as a product-development milestone. Only content required to be learnt needs to be chosen, with a record of what has already been achieved and prior experiences being stored for each learner. Therefore, an individual in industry or academia can return and continue with his or her learning activity from the same point that he or she previously left from. This allows individuals to spread their learning over the allocated duration, which is convenient for them, especially in a working environment (Steed, 1999; Ravet & Layte, 1997).

An e-learning programme can provide pre-tests for each learning activity to assess what specifically each learner needs to achieve to fill in his or her missing knowledge or skills gaps. Thus, the timeframe can be customised according to each learner. This can also reduce the amount of learning time required for the learner who already knows specific content within the programme, module, lesson or task. A lesson timeframe can indicate the allocated running times for instructor-led online sessions for learners to appropriately log into, or times when peers are online for participating in synchronous collaborative learning activities. In WMG, these timed learning activities are being tested and developed to complement the instructor-led classroom teaching. However, asynchronous communication provides a more self-directed approach due to individuals having control of their learning activity times. PMAs, which are part of the MSc course at WMG, need to be completed within a timeframe of six weeks after the instructor-led module week. In industry, such as with Company X, the learning timeframe is dependent on the task at hand and so is often required to be achieved immediately. The next section discusses assessments, which also can have time restrictions associated with them.

4.3.5 Learner Assessments

Knowledge acquisition and assessment are both learning activities. This section focuses on assessing learners' performance, which involves measuring their participation within learning activities as well as their achievements from learning. This incorporates assessment activities such as tracking progress, testing understanding, grading and recording work, and providing adequate feedback to assist learners to advance in their working or learning environments. Acquiring knowledge and assessing performance in an e-learning environment can range from reading electronic information and being tested online using multiple-choice questions, to interacting with peers in a VLE and having feedback from them in an online forum.

Electronic assessment tools can make grading and recording of assessments, especially multiple-choice questions, more efficient than traditional paper-based methods as scores can be tabulated immediately, providing fast and accurate feedback to the learners (Steed, 1999; French et al, 1999). However, answering multiple-choice questions involves little experiential experience for learners, especially if a test score result is the only feedback. A more effective way of assessment, as Ravet & Layte (1997) point out, is to allow learners to monitor their own progress through problem-solving exercises. This requires them to use what they have learnt and only refer back to the content if further explanation or guidance is required. Thus, self-directed 'discovery' learning is integrated with guided 'structured' learning. Learners have the opportunity to manipulate concepts and rules to validate theoretical models, and build a representation of their own knowledge, which can be shared, discussed and assessed with their peers or instructors, as well as reflected on by themselves (Ravet & Layte, 1997).

However, the self-directed learning assessments can still have boundaries impose on them, such as timeframes. Timeframes set milestones for completing learning activities, i.e. the expected time to acquire the knowledge or skill, and time given to complete the assessment. Timeframes were discussed in section 4.3.4. Hall (1997) points out that when developing e-learning lessons, adequate time needs to be given to the learners mastering a learning activity prior to them progressing to the next activity. Measuring learners' performance can take into account their time taken to accomplish each activity. Excess time taken can then result in marks being deducted. For example, each day a MSc student's PMA is overdue at WMG, i.e. past the six weeks from when the module finished, one percent is deducted from the PMA's final mark. PMAs being late due to printer problems, the Royal Mail, or physical restrictions are now not issues for WMG. Since October 2005, PMAs are required to be submitted electronically over the Internet to WMG's MSc Course Administration Office. The submissions are done via the MSc's website where a student logs into his or her secure workspace, selects the appropriate module, and then uploads the PMA file. The student's library card number is added to the beginning of the PMA file for added security and ease of identification at the Administration Office. A challenge for designing electronic assessments is knowing that the learner being assessed is genuine. Providing a secure environment is important for the e-learning content being assessed, and this needs to be properly managed to ensure correct authorised use and safe content storage. Section 4.3.1 described security issues and ways to determine a learner's correct identity.

Learner assessments can be mid-activity self-assessments and peer-assessments, as well as having the normal pre and post-activity assessments, such as instructor-based tests. A post-activity assessment examines the learner's competency level, which identifies what has been understood and ability the learner has with mastering tasks. This also determines if the instructional objectives have been met. A pre-activity assessment can test the learner's prior knowledge before embarking on an e-learning activity. Then if necessary, the learning content can be tailored to particular learning requirements or styles. Figure 4-4 illustrates a diagram developed by the author to show the areas that contribution to the learner's acquisition and assessment of knowledge and skills.

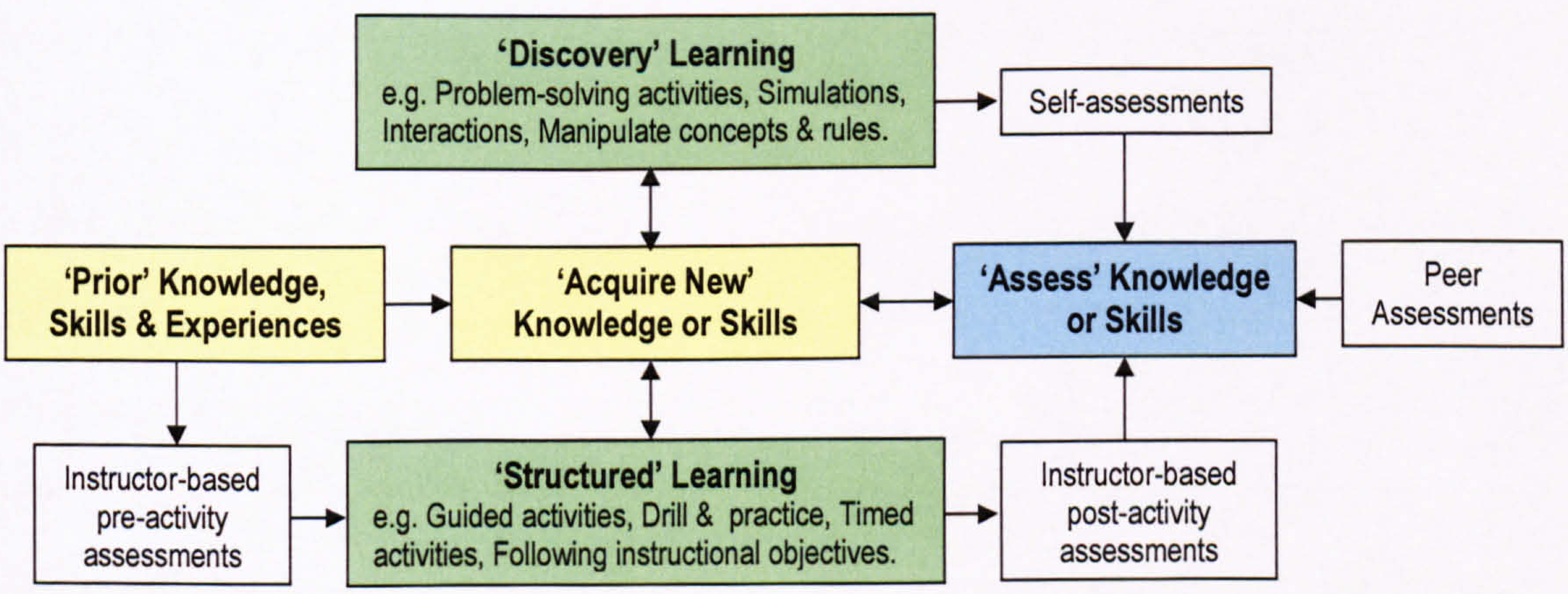


Figure 4-4: Contributions to Acquisition & Assessment of Knowledge & Skills (James-Gordon, 2004a)

Post-activity assessments follow the taught part of the E2BM MSc modules at WMG, in the form of PMAs written up by students and marked by Module Tutors. The PMA is an extension to the module and enables students to build from the learning content presented and draw upon their prior experiences. The best PMA marks, from nine of twelve modules attended, are taken forward and contribute to 50% of the overall E2BM MSc grade. The student's dissertation makes up the remaining 50% of the overall MSc grade. However, pre-module assessments and mid-module work can also contribute to 15% and 30% of the total PMA mark respectively. Investigations into pre-module work at WMG was mainly for 'Global E-Business' (GEB), 'E-Commerce Technologies' (ECT) and 'Finance for E-Business' (FEB) modules as these initially had the most e-learning activities developed compared to the other E2BM modules. The aim of pre-module work is to bring students up to a similar knowledge level, familiarises them with the topic's terminology and concepts, and practice and check their understanding before they embark on the taught classroom lessons. The pre-module work at WMG has involved being introduced to the module's topic by first reading case studies and/ or recommended literature, and then being assessed on this topic using online multiple-choice tests. Initially, there were problems with the multiple-choice tests on the E2BM MSc course at WMG, as students were able to have several goes at the test and then share their answers with fellow students. Therefore, limiting the students to one attempt at the test solves this, as they are only given valid access permission to the test once. GEB module initially had pre-work distributed to the students via compact disks (CDs). These CDs contained information to help students familiarise themselves with the e-learning website as well as introduced them to the module by using a video clip of the Module Tutor describing the topic. Presently, the GEB module has mid-module assessments based on syndicate group exercises, which requests all associated working activities and outputs by the students to be posted to discussion forums. Thus, WMG provides pre, mid and post-activity assessments on its E2BM MSc course.

Pre-activity assessments are performed at Company X prior to any CAD training, especially when recruiting new engineers. These are predominantly based on engineers' profiles and face-to-face interviews with them discussing their previous CAD experiences. This enables Company X to group together engineers who are competent CAD users and provide them with shorter courses, than engineers who have no CAD experience. Additionally, in 2005 Company X introduced a Web-based assessment product called 'Pro/FICIENCY Evaluator', developed by their CAD vendor. This assesses engineers' skills and understanding of the CAD software, Pro/Engineer, by using multiple-choice questions and a design exercise which compares the geometry created with its stored solution. 'Pro/FICIENCY Evaluator' is particularly effective for Company X when screening potential employees who state they have existing Pro/Engineer CAD skills. This product is also used to determine when their engineers are ready to take the advanced Pro/Engineer CAD training courses. The latter activity is often used as a self-assessment tool at Company X, as their engineers generally request advanced CAD training when they feel confident with their basic CAD skills, and they use this tool to check their competences. The reports generated by 'Pro/FICIENCY Evaluator' identify engineers' strengths and weaknesses in functional areas of Pro/Engineer. This information feeds back to all learning stakeholders in Company X and suggests whether improvements need to be made. This assists their engineers to track individual CAD progress as well as their instructors to develop bespoke or refresher CAD training courses for specific groups of engineers.

Incorporating appropriate feedback techniques are important aspects in developing assessments as they can influence the level of satisfaction of the learners, as well as affect the quality of their learning experiences. Feedback techniques were described in section 4.2.3. Developing assessments needs to consider the different learning modes in the activities, because different levels of support can be required. For example, self-directed or problem-solving modes are more likely to need self-assessments developed in the learning activities than instructor-led assessments. Learning modes were identified in section 4.2.1. Thus, integrating and optimising relevant management and delivery factors with appropriate technology assists in refining and enhancing the learning content, and helps to construct quality learning assessments. This is illustrated as area H on the framework's figure 3-1 and the guidelines' figure 3-5(ix).

In summary, the main considerations for designing assessments that the research identified, predominantly from the case study work, are summarised as:

- Utilise existing knowledge and prior experiences of learners appropriately.
- Provide for different learning modes, e.g. guided or self-directed assessments.
- Cater for different learning styles of learners.
- Have appropriate presentation of the questions and answers, corresponding to the learning objectives.
- Incorporate appropriate self, peer and instructor assessments activities.
- Encourage learners to apply their knowledge to relevant applications and tasks.
- Measure learner participation, such as sharing information with peers, as well as measure learner achievement.
- Test problem-solving skills and not just recall skills.
- Provide appropriate and responsive feedback to the assessment, which not only provides the test score result, but also solutions and references to further learning material and activities.
- Set realistic timeframes for completing activities and provide a way of tracking and recording time taken. This is useful for learners to monitor as well as the instructors.

Steed (1999) points out that results from an assessment provides information about the level of understanding, quality of content and future instructional needs of the learners. This information can be used by instructors to develop improved learner assessments, and learners can use their assessment results to develop a learning plan. Additionally, information on collective assessment results can be utilised by managers at a strategic level for a complete learning evaluation. Assessing learners' performance only contributes to part of learning evaluation. The next section identifies the reasons for evaluating e-learning and techniques to measure learning effectiveness.

4.3.6 Learning Evaluations

Measuring the value of educational content or skills training content has often been a reactive process in organisations (Phillips, 1997), and this was reflected in the WMG and Company X case studies. However in the industrial organisations researched, the status of the training function has been growing, with training becoming more of an integral part in the organisation's competitive strategy. More accountability has been necessary, and so efforts to measure and evaluate the success of training have increased. Academia has slightly different requirements, as accountability has primarily been measured on student pass and fail-rates, but evaluating the effectiveness of learning is still important for academia as well as industry. The reasons for evaluating a learning environment, in particular an e-learning environment, were detailed in submission 4. The evaluation process helps e-learning providers make improvements to the content, technology, delivery and management of e-learning. The main reasons are identified as:

- To determine the strengths and weaknesses in the content.
- To determine the strengths and weaknesses of the supporting technology.
- To establish future development requirements.
- To understand and verify the usability of learning activities, such as online tests.
- To determine cost benefit comparisons with traditional, other or former programmes.
- To identify if the solution chosen is appropriate for the specific need.
- To ascertain if the programme's objectives have been successfully achieved.

In order to improve subsequent learning or training programmes in organisations, Rosenberg (2001) comments that the 'Kirkpatrick Model' (Kirkpatrick, 1996) is often employed to determine learning effectiveness, and this was reported in submission 4. The four evaluation levels of this model are summarised next using the case study examples:

- **Level 1 - Reaction:** Measures how learners react to or feel about a lesson or complete programme. This can be shown in questionnaires, such as 'smile sheets' that are filled in at the end of the course by the learners, and this provides a measure of the individual's satisfaction. This was adopted at Company X after instructor-led CAD training and at WMG after the module running, where both organisations gave out evaluation forms.

- **Level 2 - Learning:** Measures the extent to which the individual's knowledge, skills and attitudes has changed as a result of learning activity. Examples of this learning level evaluation are shown by pre-activity tests and post-activity tests, with the difference between the two being the gain in knowledge or skills tested being measurement of learning. Learner assessments were discussed in section 4.3.5.

- **Level 3 - Behaviour:** Measures the extent to which the individual's behaviour has changed because of the training and learning. This level attempts to measure 'on-the-job' performance changes resulting from the training and learning. After the CAD training at Company X, engineers learnt 'on-the-job' and actual work-based designs were produced. However this was not formally measured at Company X.

- **Level 4 - Results:** Measures the final effects that occur because of the learners attending lectures or training courses, or the impact on the organisation. In academia, the result is obtaining the qualification, and in WMG's case this meant the MSc degree. However in industry, results are not so easily recognised and are often over a longer time-scale, which can be measured as return on investment (ROI), increased production, decreased costs, improved quality or higher profits for the organisation.

Although instructors generally accept Kirkpatrick's model, the author concluded that it is rarely implemented completely. As the role of training is changing in many industrial organisations to a valued and accountable function, evaluating present training methods is important to build on for future training programmes. Existing engineering training methods were investigated in two automotive companies, as reported in submission 1. Ways to measure the effectiveness of training needs to incorporate organisations where learning is an integral part of work activities.

Submission 4 described evaluating the effectiveness of e-learning content by measuring the achievement of the learner, which was based on learning requirements and instructional objectives being met, as discussed in sections 3.3.1 and 3.3.2. The progress of learners can be derived from their basic responses to questions, through to learners' demonstration, integration and application of knowledge, to finally their project's outcome. The techniques used to measure learning depend on the type of learning that the activity or complete programme has been designed to achieve. Organisations can employ external training professionals or consultants to advise them on how new training methods can help their organisation. This was illustrated in the WMG case study, which was reported in submission 5. Learning instruction delivered via the Internet or Intranet, like any other instructional procedure, still requires the use of evaluation methods to measure its effectiveness.

Phillips (1997) points out that the change in training delivery comes at a time when departments in organisations are being held accountable for their actions and they need to demonstrate how their efforts add value. The investigation and practical experience have shown that e-learning can be educationally effective, offer business value and be cost-effective after the initial high development costs. However, considerations affecting e-learning effectiveness not only come from providing quality content and incorporating appropriate philosophy, delivery and management factors, but from also taking into account the available technology. Although this research has emphasised that technology needs to be aligned to e-learning content and not visa versa, current technology capabilities do need to be understood prior to this alignment, in order to develop the content to its full potential. The technology category is discussed next.

4.4 Technology Category

Technology provides the infrastructure to shape e-learning content being developed, by considering the initial learning content with relevant factors in the philosophy, management and delivery categories of the framework. This category prompts the e-learning providers to identify and select the 'most appropriate' enabling and supporting technologies to construct activities for the e-learning content. In this instance, the 'most appropriate' technologies refer to those that are currently available, applicable to the activity being developed, and within the e-learning programme's budget. The enabling and supporting technologies, such as computer-based and Web-based products, are classified by the author as 'hard' learning technologies to distinguish them from the non-tangible enhancing 'soft' technologies that were also examined. The author felt that it was important to investigate 'soft' technologies, such as 'smart' drugs, nutrients and subliminal learning influences, to provide a balanced approach to the TBL tools and techniques researched. The literature on 'smart' drugs and nutrients claimed to enhance cognition, by improving memory, reasoning and concentration (Pelton & Pelton, 1989; Dean & Morgenthaler, 1991; Lidsky & Schneider, 2001). Subliminal learning influences were identified to create a mindset that is favourable and receptive to learning (Eysenck & Keane, 2000; Taylor et al, 1989). These controversial 'soft' technologies demonstrated the various facets of technology, but they are beyond the scope of the e-learning framework.

The 'hard' technologies, especially Web-based tools and techniques, have been of particular interest to this research because of their wide reach and interactive impact on the modern working and learning environments. The technologies are not detailed in this document due to their vast range, but a selection of TBL tools and techniques employed for developing e-learning content were examined and reported in submission 2. These comprised of various Web-based and computer-based tools, e-learning standards, electronic communication and collaboration tools, and software products used for creating e-learning activities. Bespoke tools, such as the platform developed at WMG, were also part of the technology category.

E-learning industry standards are important as they specify how content can be delivered seamlessly over multiple platforms. Accredited standards were described in submission 2, and these describe are those being developed by the Instructional Management System (IMS) Global Learning Consortium and the Advanced Distributed Learning (ADL) Initiatives (Ryan et al, 2000): IMS develops open specifications for facilitating online distributed learning activities, such as exchanging student records between administrative systems. IMS's focus is on metadata for tagging learning objects and defining how a LMS can communicate with other applications. SCORM is the main ADL's initiative, which has been adapted from the best practices of other e-learning standards and specifications, to provide a collection of e-learning functions to help enable accessibility, reusability and interoperability of e-learning content. E-learning standards and specifications have been investigated at WMG, but their e-learning developments do not comply completely yet, particularly with the limited reuse of their e-learning activities. Reusable learning objects comply with the SCORM standard as described in section 4.2.4.

Commercial software packages for assisting in e-learning development, delivery and management were also examined in submission 2. This helped to establish what products were available, what their capabilities and limitations were, and how they compared to each other. The continual evolution and fragmentation of many of these packages made classifying them, according to their purpose, difficult, as discussed in section 1.3. Therefore, a selection of key software products, i.e. tools and packages, utilised in e-learning were researched from many sources (Khan 2001; Urdan & Weggen; 2000; Harris & Shepherd, 1999; Steed, 1999; Young et al, 1999; Hall, 1997), based on their commercial popularity or availability at WMG. These products were reviewed and classified depending on their core function, into authoring tools, course management systems (CMS) and LMS. The main comparisons between these products are shown in table 4-1. Education delivery systems were also reported in submission 2, but since its write up, their functionality has now been incorporated into CMS.

Table 4-1: Main Comparisons between Authoring Tools, CMS and LMS (James-Gordon, 2002a)

	Authoring Tools	CMS	LMS
Software Architecture	Closed	Closed	Open
Smallest learning component	Object / Lesson	Lesson / Course	Module / Course
Learning content Stored	Local database	Small scale database	Enterprise-class SQL database
Student records management	Limited	Yes	Yes
Allows assignments to be viewed across multiple courses	No	No	Yes
Integrates with other vendor's products	Rare	Rare	Yes, interoperable
Content development tools	Basic	Basic, with imported features	Generally, external content development tools
Content presentation flexibility	Rigid	Templates	Flexible
Content delivery mode	Synchronous & asynchronous	Asynchronous, generally	Asynchronous tools built-in. Integrate to external delivery systems
Grading and reporting capabilities	Limited	Exported	Imported and exported
Target audience	Broad range	Universities, generally	Universities & Company Training Departments

Authoring tools were initially used by WMG's Instructional Developers for creating a bespoke platform to package its educational e-learning content using standard templates, as well as to incorporate the developers' Web programs. However, due to the ongoing development and maintenance required on the bespoke platform, and constant dependency of Module Tutors on the developers, the e-learning management team at WMG decided to consider alternative e-learning solutions. The decision to outsource the development resources was initially considered as a more efficient way to provide the e-learning systems and services required at WMG. Yet, after a few pilot runnings of the GEB and ECT modules on the E2BM MSc course, problems started to arise with the external providers' solutions. These problems were licensing, ownership, control, hosting and security related issues as well as their restricted functionality, flexibility, support and training given. Therefore, the decision was made by the management team to bring the development back in-house and take advantage of the dedicated e-learning tools that were starting to be supplied and supported by E-Lab. This has been an attractive solution for WMG, as there were no direct costs incurred. E-Lab has been set-up to allow Modules Tutors to develop their own e-learning activities and upload content for their modules. Support is provided by the two remaining developers, but only when requested by the Module Tutors. The different e-learning development approaches adopted at WMG were detailed in submission 5.

E-Lab's development tools are similar to those provided by CMS software products as they enable Instructional Developers and instructors to create and deliver e-learning content with little or no expertise of Web programming languages. The development tools built into a CMS, allows webpages to be created, documents uploaded, online quizzes and tests designed, and features added such as threaded discussion. Brennan et al (2001) comment that CMSs are becoming more like LMSs with their increased flexibility and functionality, like the addition of management tools, but rarely do CMSs support third party products. However, LMSs supply limited content development tools, but provide the flexibility of integrating with other vendors' products, for example delivery systems and content development tools.

Since submission 2 was written up in 2002, the learning content management system (LCMS) has been introduced, which incorporates features of CMS and LMS with authoring tools. LCMS combines administration and management capabilities of LMS with content creation and storage capabilities of CMS, to manage the creation, storage, delivery and reuse of e-learning content from a central learning object repository. An advanced LCMS can also dynamically assemble learning objects based on a learner's profiles and learning styles, and so can develop customised learning content to meet individual, department or company requirements. (Brennan et al, 2001). Learning objects were described in section 4.2.4. Designing effective learning objects takes foresight, planning and skill, even when templates and examples are provided. Thus, Instructional Developers need to consider the different contexts in which an object will be used and reused. While technology exists to develop e-learning content, even at object level, this does not mean that effective e-learning activities will be created.

Therefore, when an organisation plans to develop e-learning activities from scratch, or to complement or replace existing instructor-led lessons, it is important to involve all the necessary stakeholders and draw on their expertise. The appropriate technology needs to be designed to support the e-learning activities, and not imposed on them. Otherwise the e-learning developments can fail to achieve their expected benefits (Ravet & Layte, 1997). This was experienced in the WMG case study. The technology-led solutions from the external providers initially controlled WMG's e-learning development, and the learning content was implemented onto each of their technology platforms being trialled. Also, the external providers predominantly promoted their products to key decision makers at WMG, i.e. the management team, who were not the end-user e-learning providers, i.e. Instructional Developers and Module Tutors. These stakeholders at WMG needed to be engaged at the start of the e-learning programme and involved with key decisions regarding the suitability of the technology selected, as well as being allowed to input their e-learning requirements. Then, as Ismail (2002) remarks, the development of e-learning activities does not become a technical process, resulting in expensive implementations often untouched by stakeholders.

Nevertheless, each learning activity being designed within a lesson, module or programme needs to consider the appropriate technology's capabilities and its limitations. This is to ensure that the design of any e-learning activity does not go beyond the abilities of the technology, nor compromise the design by under estimating the potential of the technology. Hence, arrow J on the framework's figure 3-1 is bi-directional. Once the technology's capabilities are known, they can be examined for supporting specific e-learning environments, as identified by the case studies undertaken and reported in submission 5. Thus, understanding the functionality and flexibility of the available products and technologies is important for selecting and aligning them to the e-learning activities being developed.

Another example of technology advancement, since 2002 when submission 2 was written up, is the increased bandwidth capability over the Internet. This has meant that video content can be streamed faster and at better quality. Additionally, one of the fastest growing segments of the Internet over the past years has been Web-logs or 'blogs' (Weller et al, 2005). Blogs have similarities to discussion forums where individuals post and reply to comments, thus developing discussions. However, blogs are outward facing and principally a one to many form of communication, whereas forums are principally many to many. Another difference between these two communication technologies is the control over the audience selection and content posted. The audience for a blog is chosen by the individual: In an educational setting, a blog can be private to a learner or instructor only, restricted to a small student group, or public to a wider learning group. The blog technology allows for online publication of learning diaries, portfolios and plans; information storage and retrieval; as well as connection of communities (Farmer & Bartlett-Bragg, 2005; Blood, 2002). Thus, blogs help to foster a self-directed learning environment. At WMG, blogs have not yet been utilised on the E2BM MSc course. The author has discussed with WMG's two remaining Instructional Developers, the following areas where blogs can assist their e-learning environment by providing:

- **A forum and workspace, restricted to a small syndicate group in a module, to:**
    - Discuss and share resources with other syndicate members.
    - Post work to be commented on within the group.
    - Record group activity work and results.
- **A private workspace for a learner to:**
    - Record and reflect on his or her progress in a learning diary or journal.
    - Publish project work and PMAs in an individual e-portfolio.

  - Store useful information and links specific to the learner.
  - Develop individual learning plans.

- **A private workspace for a Module Tutor to:**
  - Deliver module news or learning material to students.
  - Post comments for prompting discussions from students.
  - Develop module content.
  - Discuss issues with a particular student or group of students.

- **A public forum for an individual posting information to:**
  - Obtain technical assistance.
  - Gain feedback on project work or papers from special interest groups.

Hence, blogs become collection, connection and distribution points for an individual or small group and provide new opportunities for self-directed and collaborative learning. Due to the fast pace that technologies progress, they need to be reviewed regularly. Consideration needs to be given to possible applications of newly emergent technologies, in order to effectively enable, support or enhance e-learning activities.

The technology category and other categories described in this chapter provide the scope of the e-learning framework. They have illustrated that disparate learning factors contained within the framework's categories need to be considered and appropriately adopted when developing activities for an e-learning lesson or complete programme. Additionally, the scope of the e-learning development needs to take into account higher management issues, such as business objectives, organisational change and continual improvements for an e-learning programme to be implemented successfully. Thus the author developed CSFs to provide a strategic action plan for the management team considering or instigating an e-learning programme. These CSFs relate to certain learning factors in the framework and are discussed next.

5.0 CRITICAL SUCCESS FACTORS FOR E-LEARNING

The previous two chapters have explained the process of developing effective e-learning content for engineering environments through selecting, linking, and ordering appropriate learning factors from the e-learning framework. However, this process only examines the specific creation of e-learning activities that make up the content and does not take into account wider business issues for the holistic e-learning development. A way of ensuring that business criteria are met is by considering Critical Success Factors (CSFs). This management research method described by Rockart (1979, cited in Avison & Fitzgerald, 1995) identifies business factors that are considered important for an organisation to succeed and cope with change. Therefore, CSFs were devised by the author, associated with change relating to an e-learning implementation, which dealt with organisational and human factors, as well as technological issues. After establishing these CSFs, the author applied them to the WMG case study, which was written up in submission 5. WMG was chosen because Cisco Systems' e-learning environment had already been developed and Company X had yet to obtain full management support to further its e-learning environment. Thus, the CSFs presented in this chapter relate to WMG's e-learning environment, and where limited information was available, generic issues are discussed and drawn from previous points identified in this document. The e-learning environment studied at WMG consisted of lessons within week-long modules that contributed to the E2BM MSc course.

The five-stage instructional development ADDIE model (Harris & Shepherd, 1999; Khan, 2001) was used by the author to group the CSFs into the different stages associated with the holistic e-learning development. Figure 5-1 illustrates this and is colour-coded to help cross-reference the CSFs with corresponding areas of the framework's categories, as shown by the key. The CSFs are identified under the appropriate ADDIE stages in the following sections.

Front-end CSFs

Analyse E-learning:

1) Obtain management support & commitment
2) Identify type of consumers (learners)
3) Identify business objectives (inc. budgets)
4) Understand consumer needs
5) Rigorous evaluation of external providers
6) Establish initial learning content & requirements
7) Identify learning objectives

CSFs
Design, Develop & Implement E-learning:

1) Involve & train stakeholders
2) Build instructional principles
3) Create quality learning experiences
4) Cater for different learning domains
5) Customisation of content (inc. learning styles)
6) Use appropriate technology
7) Consider standards for WBL
8) Create collaborative activities
9) Cater for different learning modes
10) Create consistent & manageable User Interface
11) Provide management & learner tools
12) Consider security issues
13) Provide for expansion, i.e. scalability

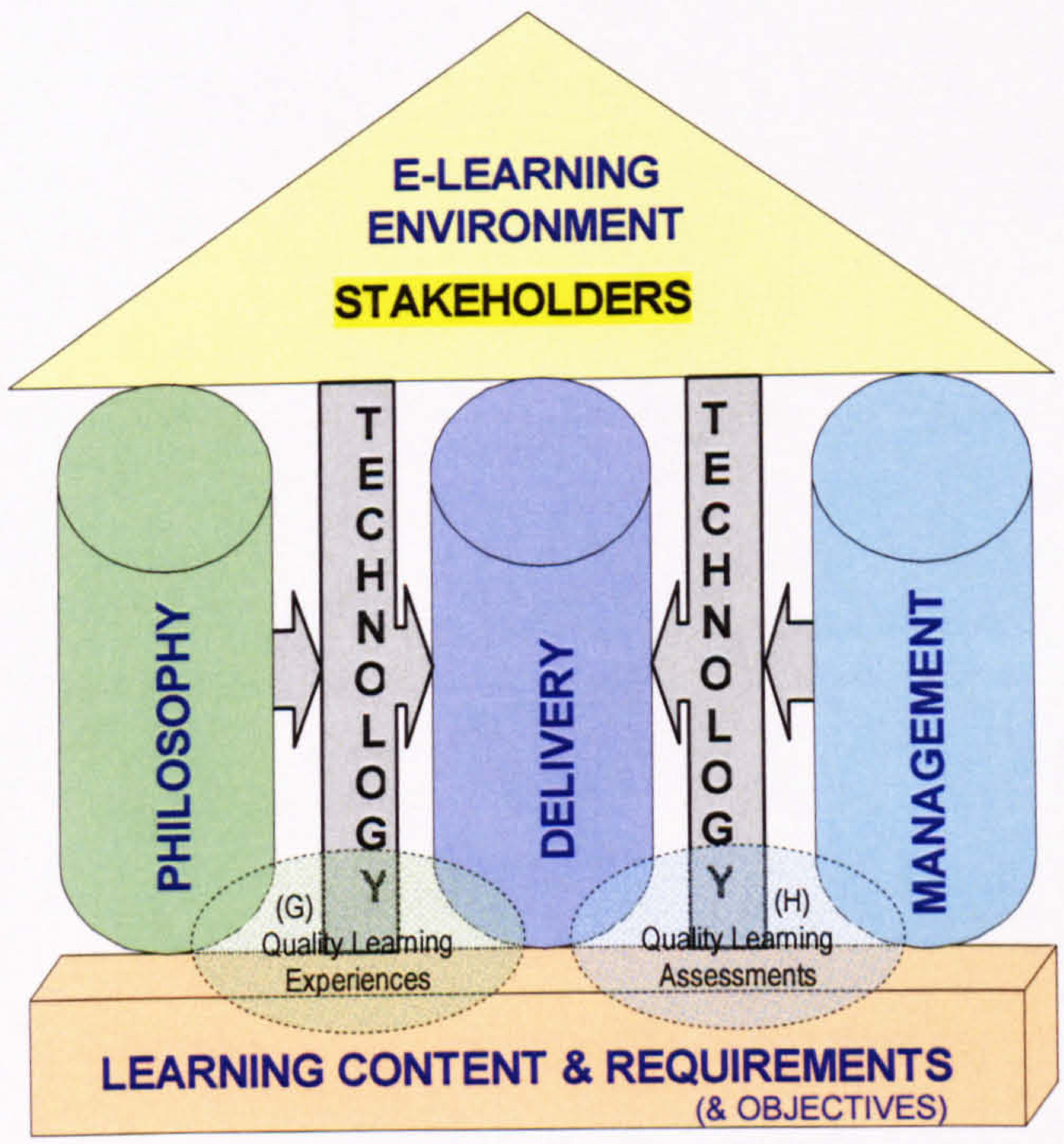
Back-end CSFs

Evaluate E-learning:

1) Evaluate e-learning functionality & acceptance
2) Assess learner performance
3) Evaluate training / learning effectiveness
4) Determine cost effectiveness / ROI

KEY: Framework Colours

ORANGE = Learning Content & Requirements
GREEN = Philosophy Category
PURPLE = Delivery Category
CYAN = Management Category
GREY = Technology Category
YELLOW = Stakeholders



KEY: E-learning Framework

Figure 5-1: CSFs of E-Learning Development using ADDIE Model (updated James-Gordon, 2004a)

5.1 Analysis Stage

The front-end CSFs are important organisational and human factors that need to be addressed before any practical e-learning development begins, in order to increase the changes of accomplishing and maintaining an effective e-learning environment. One of the most important CSFs to fulfil when considering e-learning is to have management support and commitment at the beginning of any e-learning discussions as well as ongoing throughout its development. With this in place, the target consumers can be identified and their needs analysed. These considerations assist the management team to plan an e-learning solution for a specific audience. This stage influences the rest of the CSFs, shapes the initial learning content and identifies the requirements on which to build the e-learning activities. Subsequently, the learning objectives are identified, which need to be aligned to the overall business objectives (Phillips, 1997). External providers can then be selected where required, to provide any necessary third-party e-learning content, technology or services. These front-end CSFs are equally important, but gaining management approval is a pre-requisite and is discussed first:

1) **Obtain management support & commitment:** With any organisational or process change, it is important to have senior management approval, support and commitment from the start of a programme (Gupta et al, 2000; Steed, 1999), so that responsibility is taken for any strategic decisions. The management team need to keep e-learning stakeholders appropriately informed, instigate support and resources as required, assist with technology selection, allocate an e-learning budget, as well as manage organisation change that an e-learning development brings. Two consecutive Programme Heads managed the e-learning post-graduate programme at WMG, with the assistance of Instructional Developers, Module Tutors and external consultants. Initially WMG over-estimated their support and resource capabilities, and underestimated the e-learning development time required. There was no budget allocation agreed, and E-Lab presently does not charge WMG for the use of their

tools and technology. There are presently two Instructional Developers that provide a part-time supportive role for Module Tutors requiring assistance with e-learning activities to complement their instructor-led classroom-based lessons.

2) **Identify type of consumers:** The type of learner(s) is identified in the analysis stage because the objectives, learning modes, learning styles and content need to accommodate any learner differences and requirements. WMG's main e-learning customers on the MSc courses have been predominantly academic international full-time students based at the university. However, WMG has the potential to also cater for the following type e-learning customers:

- Industrial students based in a company, who are employees seeking to further their knowledge and gain qualifications from WMG on a part-time basis.
- A department in a company requiring WMG's e-learning services to help instigate their own e-learning development. This can be aimed at e-learning providers such as subject matter experts, trainers or expert users in the company, or for Module Tutors in another university.
- An entire company requiring tailored e-learning solutions for their employees, which can also be for employees of their partners, suppliers or customers.

3) **Identify business objectives:** An e-learning programme needs to support and enable existing business plans and objectives, or as Phillips (1997) points out, it will not be seen to add value to the organisation. A programme cannot be contemplated without considering the implications on the organisation, the effects of its culture, and the constraints (Steed, 1999). The organisational culture can influence the approach taken for developing an e-learning programme. This encompasses not only having appropriate stakeholder involvement, but whether a dedicated team leads the e-learning development or if the development is left to individuals. WMG initially had an e-learning development team, but now this consists of two Instructional

Developers, as point (1) in this section explained. Constraints on an e-learning programme need to be recognised, from budgets to skill shortages, and plans need to be developed to manage a programme within these constraints. E-learning activities introduced gradually into a programme are more likely to be accepted by the users (Steed, 1999). This gradual implementation also provides a blended approach to improve and complement existing learning activities.

4) **Understand consumer needs:** The e-learning content can be designed to provide a learning experience that correlates to the learners' wants and needs, by providing them with the right information at the right time and in the right format. With instructor-led classroom-based teaching, the instructor can immediately adjust his or her teaching approach from the learners' reaction. Feedback in e-learning activities, as described in section 4.2.3, can be initially frustrating compared to traditional classroom lessons as learners cannot just raise their hand and ask for an explanation about a point made by the instructor. Therefore, the design and integration of feedback techniques are important inputs for the delivery mechanism. However, e-learning can use a mixture of delivery methods and lessons that can be tailored to meet the requirements of the learners. Information about the type of learners needs to be gathered, from their demographic profile to their computer literacy together with typical hours of study, in order to effectively provide customised learning environments. By having a variety of different media for delivering the e-learning content, different learning styles and modes can be catered for. Presentation of content is important for engineers, as the research discovered that engineers have a strong visual learning style, as described in section 4.1.3. Once the learners' needs are understood, their personalised learning model can be created. This CSF is less likely to be applied on an individual basis in an academic environment, as students are at first less informed about what is available and what is expected of them, so they are initially unaware of their own needs. Additionally, students in full-time education are

more likely to have similar knowledge levels compared to individuals in industry as was the case at WMG. This is because the majority of full-time students are at the start of their careers when they graduate, and individuals in industry often have many different experiences from a variety of knowledge and skill-sets. Therefore, subjects in academia are often broad-based with specialisation only occurring during assignments or project work. Industry generally requires more specific or customised learning for completing work-based tasks. These issues were discussed in section 3.3.

5) **Rigorous evaluation of external providers:** External providers need to be evaluated thoroughly before employing their e-learning services or products. This is achieved by checking their reported capabilities, such as reviewing past work, processes, reference sites and support available, as well as checking the experience level of their own staff and management team. As development resources were being phased out within WMG, outsourcing to external providers was seen as the quickest way to provide the e-learning technology and services required. However, there needed to be adequate in-house expertise to effectively manage the external e-learning providers, which there was not. These issues were reported in submission 5. Ideally, a strategic partnership should have been formed that provided the management of WMG's e-learning programme with a steering group co-ordinating the e-learning developments at WMG. This would have provided supplier management to monitor the external providers, as well as the e-learning expertise necessary to judge the quality and effectiveness of any technology employed and e-learning activities developed. Presently, WMG has two Instructional Developers that support the other Module Tutors part-time with their e-learning content development and functionality issues.

6) **Establish initial learning content & requirements:** The decision whether to purchase off-the-shelf content, create customised content or provide a combination of both, needs to be made by the management with the appropriate stakeholders involved. However, content required for organisational development or knowledge transfer is unlikely to be developed entirely by external providers (Ismail, 2002), as specific requirements need to be customised to working practices, methods and culture of an organisation. Section 3.3 discussed different learning content type, level and range that are required for engineering environments. The following list provides a summary of this:

- The type of content can be considered for one or a mixture of the following:
    - An 'information-base', i.e. data that is collected in context for a specific purpose and provides a repository for housing this information. An example of this at WMG is a module timetable with hyperlinks to lesson descriptions, durations and respective tutors with their contact details.
    - A 'knowledge-base', i.e. an academic theory or information in context. An example of this at WMG is the development of their 'virtual library', which housed relevant information and case studies for lessons.
    - A 'skills-base', i.e. the know-how required for a specific task and its practical application. This is not relevant for WMG, but is more applicable to the other industrial applications studied.
- The level of content can vary from content-centric to learner-centric. Many supporters of e-learning in academia, such as WMG, are enthusiastic about e-learning because of the potential it allows to provide a more flexible and tailored approach to learning. However, one of the major obstacles in adopting e-learning in universities is the extra time burden placed on tutors over the traditional content-centred approach in developing lessons. Static content can

be initially developed to present the core of a lesson, which is supplemented by tutorial support. The interaction level is low but this provides a starting point for developing most e-learning activities. Then this static content can be integrated with collaborative activities, discussion forums, online syndicate work and customised content, to provide a more learner-centred approach.

- The learning content can range from having 'immediate' or JIT activities to 'structured' or just-in-case activities. At WMG, like many universities, the content is predominantly structured with a recognised qualification being finally awarded to the learner if the learning objectives have been met.

7) **Identify learning objectives:** Clearly stated learning objectives assist learners to understand what is expected of them and to be selective when navigating through the learning activities. These objectives provide the basis of how the instruction is to be designed based on the learning requirements. Also, consideration needs to be given to how the learning outcomes can be assessed by Instructional Developers and Module Tutors. Section 3.3.2 discussed instructional objectives. The overall learning objectives need to be aligned to the business objectives to ensure the success of the entire e-learning programme (Phillips, 1997). The terms 'instructional objectives' and 'learning objectives' are used interchangeably in this document as explained in section 3.3.2. However, instructional objectives are referred to for specific, often measurable learning activities, and learning objectives are related to a more generic, holistic level taking into consideration the learner's requirements.

The analysis stage helps the management team scope the e-learning programme and this serves as the inputs to the design, development and implementation stages discussed next.

5.2 Design, Development & Implementation Stages

The CSFs in the design, development and implementation stages of an e-learning programme can be associated to the majority of learning factors in the e-learning framework categories as illustrated in figure 5-1. The management team need to guide, support and monitor these stages predominantly performed by the e-learning providers. One of the most important CSFs during the stages of an e-learning programme is to involve, train and inform all e-learning stakeholders, and this CSF is discussed first:

1) **Involve & train stakeholders:** Module Tutors and the Instructional Developers need to continue to work closely together in order to provide meaningful and relevant content, and to ensure the correct operation of the content being developed with the technology employed. This is especially important at the start of deploying an e-learning programme when prototype testing checks the functionality and appropriate alterations can be made to fix any incorrect operation. The first running of a module with e-learning activities at WMG was considered as the pilot, not only for the students and tutors but also for the entire development team. The GEB module was the first E2BM MSc module that students attended which incorporated e-learning activities. Testing and fine-tuning of the content followed from its subsequent runnings, based on the stakeholder's feedback and practical experiences obtained from the piloting process. As this module impacted on other modules in the E2BM MSc, these in turn began to incorporate e-learning activities into their lessons. However, one area that was initially overlooked at the start of WMG's e-learning programme was the need for Module Tutors to be shown and appropriately trained in how to use the e-learning tools and navigation aids. Consequently, the Module Tutors were initially self-taught and were then at different levels of expertise with using the tools. However students did receive some preliminary teaching, with brief instructions being provided in the introductory lesson of each module. Hence, this

needs to be recognised for all Module Tutors, so that provision in the future is made to build training time into the tutor's standard working day. Provision can also be made to allow students to have the opportunity to take an online induction or a refresher lesson prior to starting a new module.

2) **Build instructional principles:** Learning not only depends on the way in which the learner receives, organises and retains information, but also on the satisfaction, motivation and confidence that the learner has with the learning environment (Steed, 1999). Incorporating instructional principles into the design of e-learning activities can help to facilitate this by matching the appropriate learning principle to the learning application and if possible considering prior experiences of the learner. Teaching in academic environment or training courses in an industrial environment generally begins with following the pedagogy approach and the objectivism theory is adopted. This was demonstrated at WMG where the Module Tutors decide what the students learn and learning is initially by acquisition. This tutor-directed approach often continues in the taught classes in academia with only a student-directed approach adopted for the PMA work and project work. However, syndicate group work at WMG does provide a more andragogy approach where students can apply what they have been taught to specific case studies and bring to the group any prior work-based experiences. In this situation, students also learn experientially and improve or adjust their understanding. Kraft & Sakofs (1985) comment that reflecting on experiences helps to develop new attitudes and new ways of thinking. Thus, learning progresses from the objectivism to the constructivism theory as the case study work is controlled by the students, and learning is by participation. Section 4.1 described in detail the different instructional principles.

3) **Create quality learning experiences:** Once the learning requirements and instructional principles have been determined, the content structure can start to be

designed. The initial focus needs to be on developing relevant content, and not on the technology that is delivering the content, as discussed in section 4.4. However, the design of an e-learning activity needs to consider the technologies available, so that its design does not go beyond the capabilities of the technology or compromised by under estimating the potential of the technology. This point was also made in section 4.4, and thus arrow J on the framework's figure 3-1 is bi-directional. Activities incorporated in the learning content can be made to be engaging and motivating to the learners, by having appropriate levels of interaction being planned in the activities to encourage learner participation. The learning environment can be tailored to the learner's profile where possible, to suit different learning styles, needs, knowledge, skills and experiences, to provide a customised learning experience. Thus, integrating, optimising and customising relevant content, philosophy and delivery factors with appropriate technology, helps to refine and enhance the content for constructing quality learning experiences. This is illustrated by area G on the framework's figure 3-1 and on the key in CSFs' figure 5-1, and by the path for further continuous content improvements shown on figure 3-5(vi). Customisation of the content is discussed in point (5) in this section.

4) **Cater for different learning domains**: The learning domains represent the different motivational, understanding or communication levels of the learners as discussed in section 4.1.2. The motivational aspects of learning have been of particular interest to this research as the attention, relevance, confidence and satisfaction of the learners helps provide the initial and continual engagement with the e-learning environment. This area has not been exploited in WMG's e-learning environment as yet. This is because the e-learning activities currently utilised at WMG only supplement the traditional instructor-led environment, and the Module Tutors are responsible to motivate the student's progress through their module.

5) **Customisation of content:** Tailored learning activities can be created based on the learner's existing knowledge and prior experiences as well as other factors such as learning style preferences. Customisation helps to personalise the learning experience for individuals, which can then help to maintain their engagement and motivation to continue to learn (Steed, 1999). Pre-assessment can test existing knowledge as discussed in section 4.3.5, and if necessary, the learning content can be customised to suit each learner's requirements. Individuals can also be categorised from determining their learner type and learning paths to follow, and so their profile can be created for personalised access to certain content. Specific solutions can also be given in assessments that encourage learners to return to particular problem-based learning activities or to alternative suggested study areas. Once an individual performs a learning task, he or she can be given personalised remedial feedback to reinforce his or her answer. These areas have not been exploited sufficiently for the WMG's e-learning environment. However, consideration is being given to students with technical backgrounds to attend business modules, and likewise business-bias students are streamed to follow technical modules, and so balance their experiences.

6) **Use appropriate technology:** Relevant formats, navigation tools, and the use of multimedia are required for developing learning activities that are appropriately interactive and motivating. Yet, unconstrained use of multimedia can result in a user interface that confuses learners and makes the information harder to understand. Fortunately, care is taken by the Instructional Developers at WMG not to complicate the e-learning environment for their students or Module Tutors, and any e-learning ambiguity is identified and removed during the pilot running. Additionally, the tutors are beginning to develop their own e-learning content by utilising the available technology by E-Lab, with assistance given when required by the remaining Instructional Developers. Learning activities are thus being developed using the appropriate delivery technologies to complement existing tutor-led instruction.

Compatibility and reliability issues were investigated in the case studies, and this consisted of testing current technologies in organisations. For example, the existing hardware and Web software tools at WMG were tested, and the pilot runs checked the technology's capability as well as ensured the correct operation of e-learning activities. Section 3.4 illustrated this in figures 3-5(iv) & 3-5(viii) of the framework's guidelines.

7) **Consider Industry standards for Web-based learning:** E-learning standards and specifications for WBL, such as SCORM and IMS, have been investigated at WMG, but their e-learning activities do not comply completely yet. This is because developed activities need to be platform independent, i.e. interoperable, particularly with the server and client platforms, such as Web-browsers, operating systems, software and plug-ins. WBL standards help the growth of online learning in an 'open' environment where users can access multiple sources of learning content. The industry standards for WBL were written-up in submission 2.

8) **Create collaborative activities:** For academic-based programmes, such as those at WMG, interactive activities can involve team-based case studies and collaborative syndicate work. These can exploit the networking capabilities of the Web by linking e-learning activities to other sources of information and knowledge-bases, as well as allowing collaborative activities with other peers. WMG incorporated the following activities:

- Virtual libraries were produced to be populated and accessed by students,
- Syndicate group discussion forums provided students with an online space where they exchanged ideas and shared activities,
- Asynchronous communication via module-dedicated local email was built into the e-learning activities.

9) **Cater for different learning modes:** The different learning modes of the learning process are presentation, demonstration, guided, self-directed and problem-solving activities, as discussed in section 4.2.1. At WMG, a standard module starts at the presentation mode where the tutor explains the theory and provides the information to the class, typically using Microsoft's PowerPoint presentation software. Then the demonstration mode involves the tutor asking the class for their input and relating this to what has been presented. In syndicate group work, the guided mode provides the students with decisions and opinions of their peers as well as the tutor's assistance when required. The PMA work progresses to a more self-directed mode where the student has control of the sequence and pace of the assignment as well as the style of its write-up. The investigation for the assignment demonstrates the problem-solving mode and often consists of related work-based experiences as well as applying the newly acquired knowledge gained from the module in the assignment.

10) **Create consistent & manageable user interface:** Navigation paths and learning activities need to remain consistent in their design and use, so as to not confuse the learners. Equally the e-learning user interface design has to be consistent, logical, engaging, and cater for different learning styles. Thus, delivery factors such as usability issues are important and need to be considered. These consist of the navigation structure, readability features and multimedia application as discussed in section 4.2.5. E-learning content needs to be updated and maintained appropriately, to provide the learners with the correct material to learn. To assist with this, modular and 'reusable' learning objects for managing e-learning activities can be utilised. This learning object approach was discussed in section 4.2.4.

11) **Provide management & learner tools:** These tools help support, assess, track and grade the learners, as well as document manage and administrate the e-learning

content. Tracking the learners' performance can be based on their participation and working within learning activities or complete modules. This can incorporate tracking individuals' collaboration activities with peers and sharing of information, and not just assessing their multiple-choice or true/false tests. Assessments can be self-assessments as well as the instructor-led tests. Off-the-shelf e-learning products can be employed to provide standardised tracking, administration and reporting functions without the need to burden the in-house Instructional Developers to create these facilities separately. The tracking facilities at WMG were developed and re-used from previous trials at WMG, and now they have been updated using the present E-Lab tools, but have kept the same format.

12) **Consider security issues:** Security issues associated with e-learning need to be properly managed to ensure correct authorised use and protection of the e-learning content. At WMG, authenticating access control for each student and Module Tutor into their workspace accounts is achieved by entering a unique university username and password. Information confidentiality is important for Module Tutors at WMG delivering their specific module content to students, and for students submitting their PMAs over the Web. Thus, encryption software can ensure content passing through the Internet remains private. Virus prevention software is installed to help safeguard against electronic viruses, and at WMG, there are university imposed virus protection devices in place such as firewall and spam filters. Security issues were described in section 4.3.1.

13) **Provide for Expansion:** It is good practice that a learning programme, as well as an e-learning programme, has the functionality to accommodate for future expansion. The e-learning platform needs to allow for this further growth and cater for new technology, which is often referred to as scalability. At WMG, the e-learning functionality is restricted to E-Lab's development tools and management decisions.

However, the actual full-time E2BM MSc programme at WMG has been extended to additional provide overseas programmes, and a part-time e-learning MSc may be attempted again in the future. Nevertheless, before extending any e-learning programme, its present state first needs to be evaluated to establish if all the objectives have been met. The next section discusses this important evaluation stage.

5.3 Evaluation Stage

The evaluation stage helps the management team review how well an e-learning programme has met its business objectives as well as its learning objectives, so that any improvements can be implemented in future e-learning developments. Evaluating e-learning is similar to evaluating any other learning programme, by determining not only if the objectives have been met, but whether the stakeholders' outcomes have been fully achieved. This summative type of evaluation is acquired from evaluating e-learning functionality and acceptance, learner performance, training effectiveness and cost effectiveness, as described in section 4.3.6. However, evaluation of training and cost effectiveness is not easily determined in the short term and needs to be viewed over a longer time-scale. The main CSFs connected with the evaluation stage of an e-learning programme are:

1) **Evaluate e-learning functionality & acceptance:** There were limited resources for continual testing, measuring functionality and appraising user acceptance throughout the e-learning development process at WMG. However, initial functionality tests were carried out at the pilot stage to ensure the correct operation of the e-learning activities as well as to assess the capabilities of the new e-learning technologies adopted. Instructional Developers also conduct regular acceptance checks with Module Tutors at WMG as they work in close proximity to them. Student feedback is given on 'Module Reviews Forms' after a module running and this demonstrates the 'reaction' level to learning from Kirkpatrick's evaluation model. If applicable, this

feedback can be used to refine the e-learning content for its next running. Regular testing helps to ensure instructional reliability as well as technical functionality.

2) **Assess learner performance:** Assessment of the students' performance incorporates learner participation as well as achievement, which are both important parts of the evaluation stage of an e-learning programme. Assessing learner participation is particularly useful at a programme's pilot running as its delivery may need to be adjusted. Further performance assessments carried out at regular intervals afterwards contribute to grading the learner. At WMG, assessing student performance is possible during the module week. However, monitoring students afterwards, and their progression as a result of attending the module, is difficult and not practical without additional resources.

3) **Evaluate training/ learning effectiveness:** The evaluation of an e-learning programme is done to assist with any decision-making and accountability issues regarding the stakeholders, and to determine future instructional content requirements. Training effectiveness is often measured by the speed in which organisational performance improves. Academia has slightly different requirements to industry, as accountability has primarily been measured on student pass and fail-rates, but evaluating the effectiveness of learning is still important for academia as well as industry. Evaluating training or learning effectiveness can also consist of determining the strengths and weaknesses of the learning content, enabling technologies, delivery mechanisms and management facilities, as discussed in section 4.3.6. Determining cost effectiveness can be part of evaluating training or learning effectiveness, as comparisons can be made with traditional, other or former programmes, but this is considered as a separate CSF next.

4) **Determine cost effectiveness / ROI:** Monitoring and recording all the obtainable costs associated with the complete development of an e-learning programme can help

determine the cost effectiveness of e-learning. Initially start-up and development costs are high compared to traditional approaches, but subsequent programmes can be delivered and re-used, and so incur less re-development costs than with traditional programmes. If the learning content is not reusable due to its high speciality, complexity or short life-span, then e-learning is not a cost-effective solution, but it still may be a viable solution due to other attributes such as its flexibility. However, lower running costs can be realised from reduced travel time and associated costs for tutors and learners.

CSFs have an important bearing on the development of e-learning activities as they inter-relate with key learning factors in the e-learning framework as illustrated in figure 5-1. The CSFs need to be considered at the analysis stage of an e-learning project, through the design and development stages, to its post-implementation and evaluation stage. The latter CSFs incorporated in the evaluation stage are mainly management tools for reviewing, improving, and expanding an e-learning programme. The outcomes identified by the evaluation stage can be fed back to the previous stages in order for the design of e-learning content to be improved, refined and/ or updated. Thus, revisiting the CSFs, which relate to the design and consequently the development of e-learning content, can assist Instructional Developers produce more effective subsequent learning activities. Feeding back to the analysis stage may be necessary if the learning objectives or consumer requirements need to be re-assessed, as illustrated in figure 5-2. Hence, evaluation of an e-learning programme needs to be conducted on a continual basis. This formative type of evaluation leads to planning for continuous improvement of the e-learning activities in an academic or industrial environment.

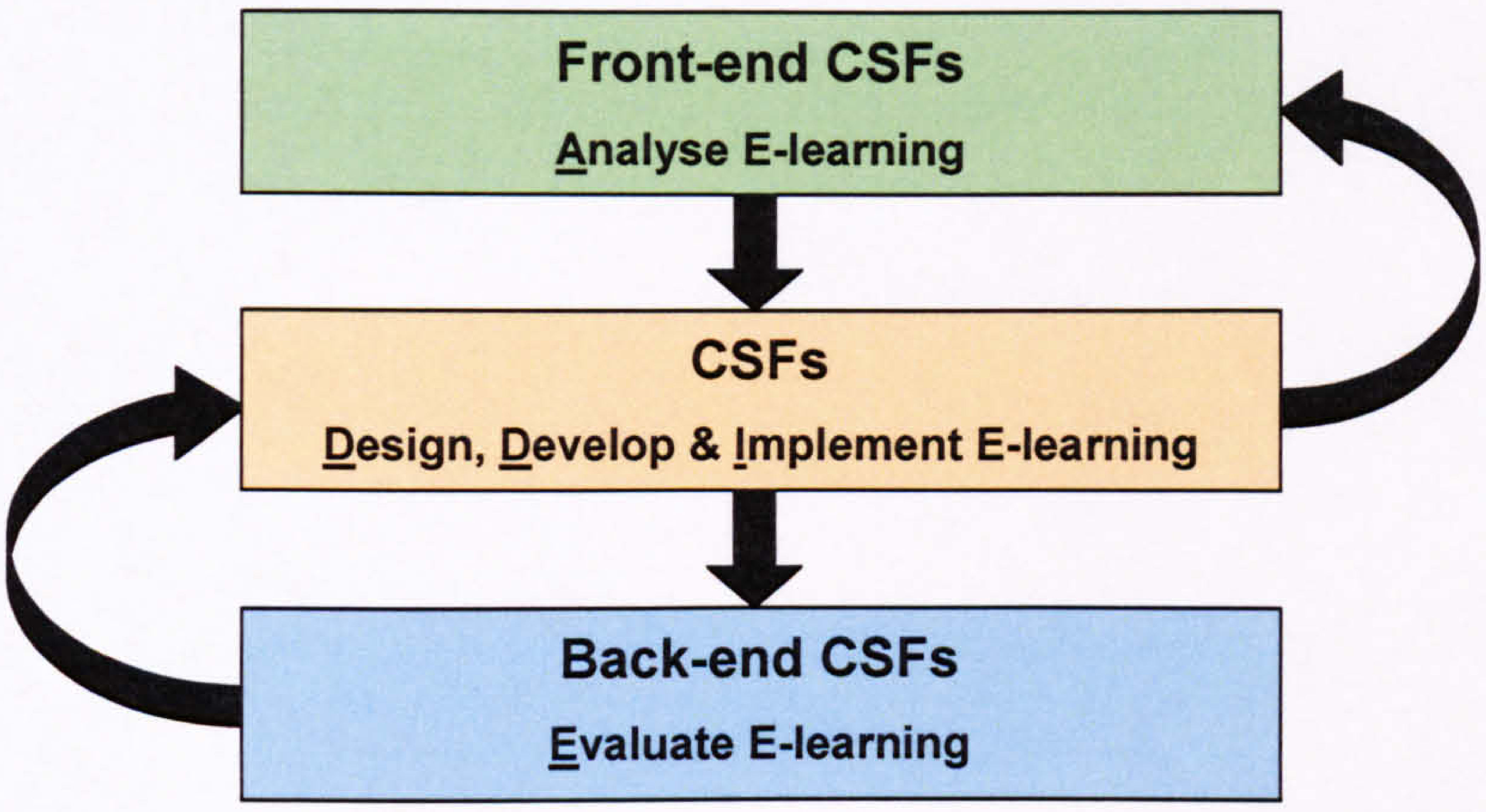


Figure 5-2: Feeding Back Outcomes in E-Learning Development (updated James-Gordon, 2004a)

CSFs provide a business interpretation in areas of the framework's learning factors. CSFs allow managers to consider relevant organisational issues when incorporating e-learning activities with existing processes and systems, and help the organisation prepare and deal with change. The action plan produced through identifying the CSFs in this chapter is based on the ADDIE instructional development model and complements the e-learning framework. These CSFs need to be continually reviewed before, during and after the launch of an e-learning programme, and then updated accordingly from their application. Therefore the framework's learning factors, together with the business CSFs, offer guidance to e-learning providers and managers respectively, to help provide effective e-learning content in engineering environments. This was illustrated in the WMG case study. Consequently, the development of the e-learning framework and associated CSFs have been strengthened from a predominant action research methodology by understanding and being involved with practical engineering learning environments. The next chapter discusses the main innovation of this research and the areas that have contributed to this from the various projects undertaken.

6.0 RESEARCH INNOVATION

6.1 Innovation Definition

Innovation is defined as the creation of a new idea, process, device, product, service or practice, resulting from study and experimentation (Wikipedia, 2005; Hornsby, 1974). However, Drucker (1964) states that innovation can also be the application of new knowledge in a way that creates change. He emphasises that the strategic importance of innovation is part of the process of shaping the future, and organisations that fail to innovate can lose direction (Drucker, 1964). Additionally, Hussey (1997) points out that creative approaches leading to innovation are necessary for business success, whether the solution lies in new competitive products, or in using new methods to provide improved and more efficient services. This latter viewpoint is more applicable to this EngD research.

6.2 Main Innovation Outline

This research has provided the innovation by developing a mechanism to facilitate and improve the knowledge assets in engineering product-development and self-development environments by exploiting e-learning capabilities. The research has been guided by the insights and applications of learning processes of practising engineers in industry and engineering students in academia, with the need to keep these engineers and students updated with the latest information, knowledge and skills. Therefore, creating effective e-learning content to satisfy this need focused on various aspects that enable, support and enhance e-learning, and these fell into the following main areas of investigation:

1) Philosophical factors of learning, such as instructional principles.

2) Enabling technological capabilities, such as Web-based tools.

3) Delivery methods, such as user interface design & usability issues.

4) Management facilities, such as support and assessment tools.

The initial investigations identified that existing e-learning research and developments were fragmented and emanated mainly from educationalists' or technologists' fields (Khan 2001; Harris & Shepherd, 1999; Steed, 1999; Hall, 1997). This was reinforced by the delegate types and the subject matter of the papers presented at the ED-MEDIA 2003 conference. For example, e-learning technologists were interested in physical Web-based tools, whereas educationalists were concerned with humanistic and theoretical sides of learning, with little evidence on how the different learning factors in these fields integrated or complemented each other. Additionally, the author was in the minority discussing e-learning applications at this conference, and the limited number of applications that were presented focused mainly on academic environments and not on engineering environments. Therefore, through researching the literature, attending seminars and conferences, and liaising with various e-learning stakeholders, it was apparent that there was limited integration between disparate e-learning factors, or specific e-learning applications for engineers. Chapter 2.0 discussed the various research methodologies adopted by the author for investigating the different aspects of e-learning. The author identified that there were gaps in the existing research and development in providing effective, holistic e-learning solutions that integrate different factors within the areas listed (1) to (4) above for engineering environments.

Consequently, the author concluded that what was required was an e-learning mechanism to help group and categorise different learning factors depending on their functionality. This mechanism then was required to guide and assist e-learning providers with the selection and integration of these factors to generate effective e-learning content. Developing some kind of methodology, model or framework emerged as an answer for this e-learning mechanism. However, e-learning development and guidance is complex because of issues encountered such as:

- Changing and varied learning content
- Difficulty in categorising and then prioritising disparate learning factors
- Keeping up-to-date with constant advances in technology

Assessing these concerns led the author to adopt a framework, as it is more flexible than a methodology or model. A framework does not have to be complete in its construction, but can evolve as the e-learning development progresses. Also different learning factors can be selected using a framework to satisfy different learning requirements, and not all learning factors need to be selected. However, a methodology works within set boundaries and a model gives repeatable sequences, whereas a framework can have many dissimilar sequences and map a variety of methodologies and models (Avison & Fitzgerald, 1995; Mingers & Gill, 1997).

The Boston Group's three-phase methodology for producing e-learning content illustrates an example of an e-learning methodology where its development boundary is set. There is no indication of providing continuous improvement for the e-learning content being developed as all the factors are considered in one pass with the validation carried out at the end of the development. Nevertheless, this e-learning methodology does take into account learning objectives and involves stakeholders other than the Instructional Developers, i.e. subject matter expects which are content providers, and in WMG's case these are the Module Tutors. Yet, this methodology is limited as it makes no provision for the philosophical aspects of e-learning such as instructional principles or learning styles. Nor does it consider management factors, such as learner assessment. Boston Group's e-learning methodology is illustrated below in figure 6-1.

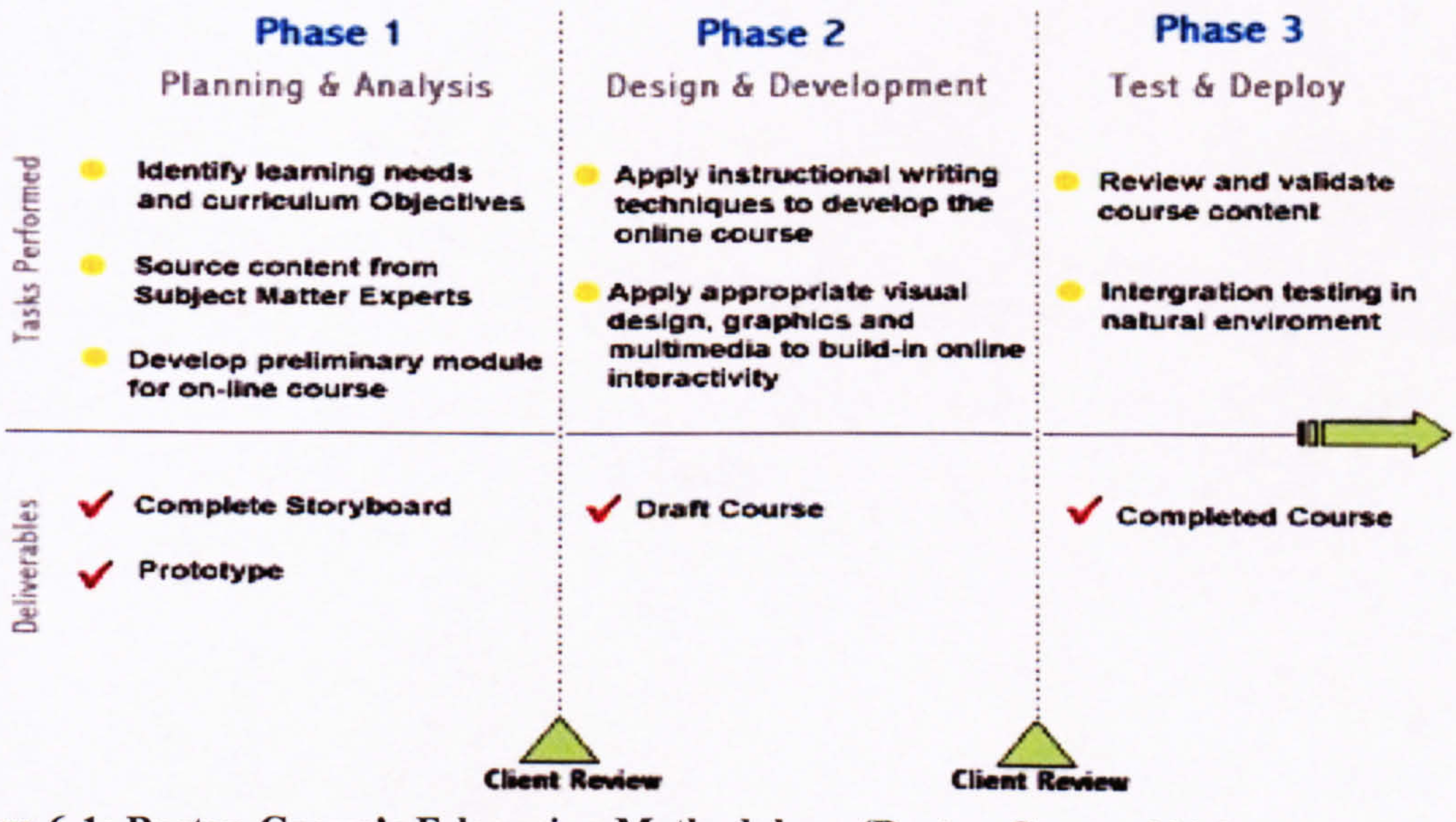


Figure 6-1: Boston Group's E-learning Methodology (Boston Group, 2006)

The rationale for adopting a framework was explained in section 3.1, but the main characteristics of the e-learning framework are summarised as:

- **A wrapper to group dissimilar factors together:** The framework groups various factors that impact on the e-learning environment into different categories depending on their main function. These categories are philosophy, delivery, management and technology, and the learning factors within them are not necessary all selected, directly comparable or even applied in the same sequence for e-learning applications.
- **Multi-dimensional models:** Different models within the proposed framework can be used to represent different e-learning developments and desired learning outcomes. The models have different combinations and amounts of features within the learning factors of the framework's categories depending on the learning requirements.
- **Bottom-up architecture:** The framework's layout and structure supports and links its categories, as illustrated in figure 3-1. The 'foundation block' of the framework represents the initial learning content and requirements. The vertical 'supporting pillars' represent the philosophy, delivery and management categories. Technology is illustrated as 'connecting ties' linking and providing the infrastructure to these other categories. The 'roof' signifies the e-learning environment and stakeholders.

Since the author's EngD submissions, there have been a number of e-learning projects that relate to one or more learning factors in the author's developed e-learning framework, but they have not addressed how the disparate learning factors can be integrated, until recently. The 'E-Learning Framework' (ELF) Programme, which is part of the larger 'Joint Information Systems Committee' (JISC) E-learning Programme, seems comparable at first glance to the author's work. (JISC is a strategic advisory committee that promotes the innovative application of information & communications technologies (ICT) in higher and further education across the UK.) ELF's primary focus is on developing and exploiting new technologies to provide a more flexible approach to the technical infrastructures for e-learning based on a 'service-oriented approach'. The software architecture to enable this approach is referred to as service-oriented architecture (SOA). The complete JISC E-learning Programme, with its associated programmes and project, plans to finish in March 2009.

Although JISC's ELF is a technical framework, it illustrates that by using SOA, disparate services can be combined to produce a collection of services, which the programme calls a 'Reference Model', for a particular e-learning activity, such as an assessment or a collaboration activity. The ELF with its services is illustrated in figure 6-2.

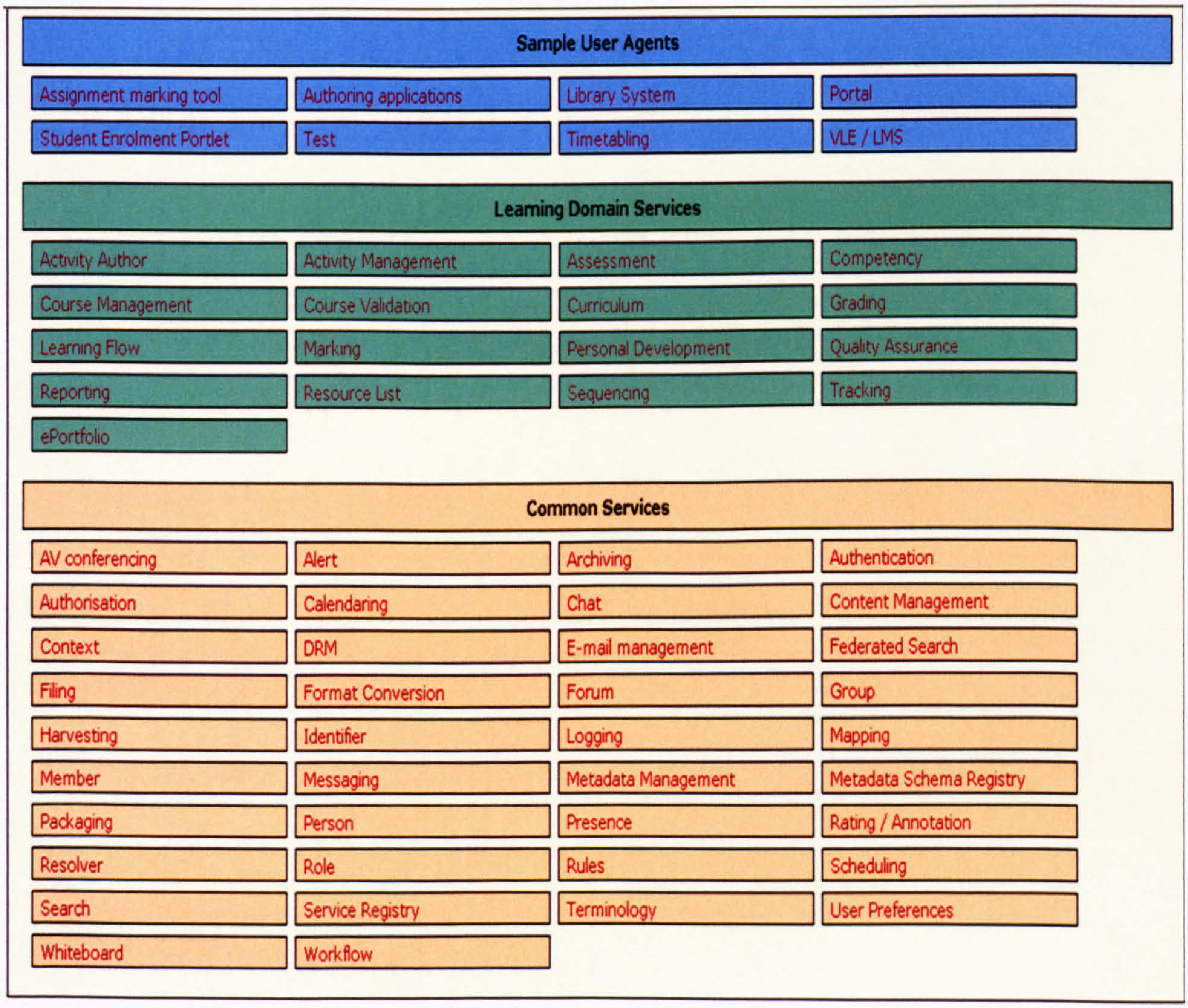


Figure 6-2: ELF: JISC's E-learning Framework (source: http://www.elframework.org/; updated Wilson et al, 2004a, 2004b)

The upper layer of boxes identifies 'User Agents', which provides the user interface for accessing the services. The middle layer is the 'Learning Domain Layer', which provides the functionality required by the 'User Agents' and specific services for e-learning. The lower layer of boxes identifies 'Common Services', which are general services that can be applied to multiple application domains, but the two former layers depend on this layer (Wilson et al, 2004a, 2004b). The ELF is still evolving as not all the services have been fully developed or have yet been identified, but an up-to-date version of it can be found on the ELF website (http://www.elframework.org/).

Projects undertaken within the JISC's E-learning Programme have been, and still are, developing Reference Models built on SOA which identify how they map to ELF. For example, the Framework Reference Model for Assessment (FREMA) Project, that ran from April 2005 until October 2006, developed a Reference Model for systems in the assessment domain of e-learning, which focused on the creation, execution and recording of electronic assessments. This Reference Model is complex as it can interact with different services in ELF, such as assessment-marking-tool, VLE and test at the 'User Agent Layer'; assessment, marking, grading, reporting, tracking, competency and personal-development at the 'Learning Domain Layer; and relies on most services at the 'Common Layer'.

The Reference Models produced from the JISC projects correspond to certain learning factors within categories of the author's framework, and services in ELF are similar to features within the learning factors. However, Wilson et al (2004c) point out that the services identified in ELF, as illustrated in figure 6-2 *"are clustered into logical groups to aid readability"*, and that there are *"no dependencies or explicit associations between service definitions"*. Therefore, ELF merely provides a structure to contain the services, and when required they are selected and combined, as described by a Reference Model for a particular e-learning activity. Although there are connections between particular services to satisfy a certain Reference Model, there are presently no connections or sequencing between these autonomous Reference Models. Hence, ELF does not guide or assist e-learning providers develop an integrated e-learning activity by considering the necessary philosophy, delivery, management as well as technology factors.

Since 2005, the ELF Programme has become part of a wider initiative called 'e-Framework', which is jointly shared by JISC and Australia's Department of Education, Science and Training (DEST). The e-Framework is building on work already completed by the ELF Programme to produce a maintainable, service-orientated, open standards-based technical framework to support the education and research communities. However, stakeholder participation is only now being considered as an important aspect for developing e-Framework, and so the Reference Models projects have been extended to include stakeholder involvement. Additionally, Olivier et al (2005) comment that the current development of Reference Models is now matching appropriate tools and services to meet different user needs. Stakeholder involvement and catering for different learning requirements are both factors already incorporated in the author's framework. However, the e-Framework is still being designed and developed as it is described as being *"largely a sketch of what may be required and there remains an enormous amount of detail to be addressed....It will be a strategic tool to support international education and research communities in their exploitation of the next generation of technology"* (JISC, 2006).

The research identified that with a technology-led solution, such as e-Framework, care needs to be taken to ensure that the e-learning developments do not end up as technical projects virtually untouched by the stakeholders (Ismail, 2002). A report conducted by Attwell et al (2003), which looked at 149 European projects involving the use of ICT in learning, identified that the majority of these projects have been technology-led. Instead of the technology being designed to support the learning, different technology applications had been imposed on the e-learning developments, and this was also experienced with the WMG case study. Inappropriate use of technology can be restricting or overwhelming for activities being created and so, as Ravet &

Layte (1997) point out, e-learning developments often fail to reach their full potential as key stakeholders, such as Instructional Developers and instructors, are not involved with the initial technology decisions.

Presently, the JISC E-learning Programme is aiming to bring together the technology developments and involve the different stakeholders to develop effective e-learning for learners, instructors and organisations. Another area associated with the JISC E-learning Programme is the E-learning Pedagogy Programme which is *"focusing on the ways in which a better understanding of pedagogical approaches can help practitioners in making appropriate use of the technology"* (JISC, 2004). The outcomes from this programme will support the effective use of learning design tools and help e-learning providers make decisions about the appropriate use of e-learning. The first publication from the E-Learning Pedagogy Programme (JISC, 2004) illustrates some of the key implications in designing for learning and comments that *"e-learning is fundamentally about learning and not about technology.* This publication was released after the author's main research work had been conducted and written up in the EngD submissions. Nevertheless, it reinforces areas of the author's work and emphasises the importance of developing e-learning that is learner-led and not technology-led, by fitting the technology to the learning content and requirements and not visa versa. However, the JISC publication (2004) goes on to say that *"strategic development of e-learning should be based on the needs and demands of learners and the quality of their experiences",* but developing e-learning based on learner needs and demands is not always practical in academia. This was discussed in 3.2, where the author explained that students are generally less informed about what is available and what is expected of them, so are initially unaware of their needs. Therefore, an e-learning solution needs to be flexible enough to accommodate both academic and industrial learning requirements and take into account different factors within the areas listed (1) to (4) earlier in this chapter.

Although there are similarities with the author's e-learning framework to areas within the JISC E-learning Programme, the main integration with disparate learning factors, i.e. its Reference Models and stakeholder involvement are only now being realised in the JISC programmes and associated projects. Current research and development undertaken by JISC in the areas of e-learning is the most predominant and cited international work. This was illustrated by the search results returned on 'e-learning framework' by 'Google', the Web search engine, in March 2007, which identified JISC's E-learning Programme and its associated programmes and projects on the first three pages. Even though this E-learning Programme is at the forefront of e-learning research and development, there are still areas where its work is fragmented and has been sporadic, i.e. stopped and started. This is illustrated by:

- The different or ambiguous hyperlinks to its various websites.
- Repeated or overlapping areas in its projects and associated programmes.
- No obvious connections between the programmes, projects and Reference Models being developed.
- Re-branding of programmes, but former programmes still continuing to be developed. Although e-Framework has evolved out of ELF, ELF plans to finish in September 2007 and e-Framework plans to finish in July 2008.

Consequently, the main innovation of the author's research has been the development of an e-learning framework that not only structures various learning factors but it also links and orders appropriate factors to suit different learning requirements. Chapter 3.0 discussed the context in which the e-learning framework operates, and explains the linking and ordering of factors that have contributed to its composition and architecture. The framework is intended for e-learning providers to help guide and facilitate their decisions, with regard to the choice and design of each feature within a learning factor for an e-learning activity. The framework's guidelines were presented in section 3.4. This demonstrated typical paths through the framework to incorporate the appropriate learning factors depending on the initial learning content material and learning requirements. The framework's factors can be selected to create customised activities to meet different engineering requirements, and these are illustrated in the matrix of table B-1 in appendix B. The main learning factors and specific features within the factors were described in chapter 4.0 under the respective category of the framework.

As the research progressed, the author realised that e-learning development also needs to consider higher management issues such as business objectives, organisational change and continual improvements to reduce the risk of failure in its implementation. Therefore, CSFs were devised to provide a set of business guidelines to help managers address these issues. The CSFs were discussed in chapter 5.0 and they can be related to certain learning factors in the framework, as shown in figure 5-1. CSFs need to be continually reviewed before, during and after the launch of an e-learning development, and then updated accordingly from an application. Therefore the framework's learning factors, together with the business CSFs, offer guidance to e-learning providers and managers respectively, to help provide effective e-learning content in engineering environments.

Although this chapter discusses the main innovation as being the creation of the e-learning framework, the framework itself can enable innovation in an organisation by assisting in knowledge creation, sharing and integration. Innovation is also defined as application of new knowledge (Drucker, 1964), and areas of the research that have contributed to gaining new knowledge and applying it, or identifying where it can be applied, are described next.

6.3 Contributions to Knowledge

The development of the framework required deeper understanding in particular areas, where there was limited information available or where further understanding of current practices was required. The case studies provided practical understanding of current engineering practices and identified areas where e-learning developments or improvements can be made for professional and student engineers in their learning environments. This led to further contributing areas of knowledge provided from by undertaking the projects, which consequently were written up in EngD submissions. These areas of knowledge have helped to support the research innovation in developing or improving e-learning content for engineers, and are summarised as follows:

1) **Presentation of learning content:** The evidence showed that the engineers investigated have a strong visual learning style preference and so best learn by what they see. This was discovered and reported in submission 1, accounted for in submission 4, applied in submission 5 and described in section 4.1.3. Additionally, the surveys and results were published in a peer-reviewed journal as presented in appendix A1, and this helped to test the acceptability of the results. Discovering the preferred visual learning style for engineers in development environments is new. This finding has not been published or mentioned before in any learned journal, paper or other literature reviewed by the author. Whether engineers are born visual learners or whether they develop visual preferences from their environmental influences is debatable, but the outcome is the same – engineers are visual learners. This means their learning is made more effective by incorporating visual techniques when developing their learning content. This involves using diagrams, sketches, photographs, schematics, flow charts, pictures, videos, computer graphics and demonstrations in training or educational programmes as well as in their everyday working environment. The present CAD functionality in the engineering environments investigated incorporates some of these visual techniques and so satisfies engineers' visual learning style preference. Thus, the user interface design, application of visual components and usability of e-learning content are important factors for engineers, and Company X and WMG were also recommended to incorporate visual techniques in their future e-learning development.

2) **Provision of experiential learning activities:** Kolb (1984) developed the term 'experiential learning' by drawing on work from other educationalists in the field such as Dewey (1938), Lewin (1951) and Piaget (1970). 'Experiential learning', or as it is often referred to as 'learning by doing', can apply to any kind of learning through experience. Kolb (1984) identified four distinct learning stages on a continuum running from concrete experiences, reflective observation, abstract conceptualisation and experimentation. Honey & Mumford (1992) developed a learning style system as a variation on Kolb's work, with four key learning styles being activist, reflector, theorist and pragmatist. These also provide a four-stage learning cycle, which corresponds to Kolb's experiential learning theory. This was discussed in sections 4.1.1.2 and 4.1.3, and reported in submissions 1 and 4. Engineers tend to work and learn experientially and cycle through different learning styles at different stages of the product-development or their self-development activities. Also engineers experience cycles of enquiry, problem-solving, continuous improvement, as well as learning. Experiential learning also takes into account differences between learners with their existing knowledge and prior experiences, and can combine their perception, cognition and behaviour. Therefore, e-learning activities need to consider these factors when being developed for engineers.

3) **Provision of self-directed discovery learning experiences:** The discovery learning approach is important for engineers in development environments due to the nature of their work in using exploratory skills to establish optimum solutions to problems. In this environment, engineers need to take responsibility for their own discovery process and are partially, if not wholly, self-directed in their individual operations and collaborate with other peers when required, as discussed in section 4.1. If individuals are allowed to be self-directed and so learn at their own convenience, they are able to manage their own learning sequence, pace, amount and time. The individual can then immediately apply their newly learnt knowledge to the required

task or problem for an industrial or academic project. Yet, self-directed discovery learning also needs appropriate direction and guidance. Point (5) discusses integrating the guided learning mode with self-directed learning mode to cater for this. The research projects undertaken identified that engineers can combine self-directed, knowledge-discovery learning with JIT, skills-guided training for specific tasks and for their own self-development. The integration of different content type, range and level is discussed in point (6) of this section.

4) **Incorporation of appropriate assessments.** Self, instructor and peer assessments all contribute to examine the learner's knowledge or skills level. An effective way of assessment is to allow learners to monitor their own progress through problem-solving exercises, which requests them to use what they have learnt and only refer back to the content for support (Ravet & Layte, 1997). Self-directed individuals can use self-assessments before, during and after the learning activities for this. Follow-up assessments of the learners' activities can provide feedback and advice, with suggested solutions or alternative routes when a problem is encountered. Therefore, the design and integration of feedback techniques are important parts in developing assessment as they influence the level of satisfaction of the learners as well as their learning experiences. Post-activity assessments test learners' competency levels, which identify what has been understood and their ability to master the tasks, as well as determining if the learning objectives have been met. Pre-activity assessments test learners' existing knowledge before embarking on an e-learning lesson. Then if necessary, the learning content can be customised to their particular learning requirements and styles. This is illustrated by area H on the framework's figures 3-1 and 3-5(ix), where content, management and delivery factors, with appropriate technology, are combined to help construct quality learning assessments. Considerations for designing assessments were discussed in 4.3.5. Recommendations were made to WMG and Company X for incorporating pre-activity assessments and

post-activity assessments during the case study work. Developing assessments need to also consider different learning modes, as different levels of support are required.

5) **Combination of guided & self-directed modes:** Engineers in their development environments experience different learning modes ranging from presentation, demonstration, guided, self-directed through to problem-solving activities, to suit their level of competence or expertise. Learning modes help provide an experiential environment that exceeds 'drill and practice' activities and progresses to the more self-directed discovery activities. The problem-solving mode builds from the self-directed mode by presenting the engineer with different learning exercises in different situations, in order to apply their own judgement as well as practise their newly acquired skills. However, guided and self-directed modes can be combined depending on the support required for the learning activity. For example, a self-directed engineer can request assistance from online help or be guided through library information whilst in the middle of an engineering calculation, to recall an engineering principle or terminology, or to seek further explanation. Additionally, this type of integration recognises that different requirements are needed on different occasions to cater for individual or collaborative learning activities. The learning modes were written up in submission 4, but due to their importance in the engineers' learning process, they were discussed in section 4.2.1 with the Company X case study drawn on for examples.

6) **Integration of relevant type, level & range of learning content:** The research identified an increasing need for professional and student engineers to combine different content type, level and range to help provide wider, transferable, relevant competencies for themselves and/or their organisation. These content characteristics were discussed in section 3.3 and exemplified by the WMG case study within point (6) of section 5.1. The content characteristics are summarised as being:

- The **type** of content required can be for an information-base, knowledge-base, skill-base or a mixture of these.
- The **level** of e-learning instruction can vary from content-centric for providing mainly standard information, to learner-centric for providing tailored content.
- The **range** of learning material required for different learning situations can be for either immediate or structured activities.

Integrating the different content characteristics provides structured, generic, content-specific, knowledge-based learning, combined with immediate, customised, learner-specific, skills-based training. This mixture of content characteristics is incorporated into learning activities to cater for the different learning requirements. This influences the design of the e-learning user interface, especially if the content and interface are customised. Developing an appropriate instructional approach to deliver and manage various content characteristics and to cater for different learner skills, knowledge and experiences is a complex process. A way to ease this is to build the content up from learning objects as discussed in section 4.2.4, which not only helps manage the content, but also allows the content to be more easily scalable. Providing manageable learning objects is outlined in the next point (7).

7) **Provision of manageable learning chunks:** The majority of the e-learning content researched had either been developed for a specific course or a complete programme. Learning broken down into manageable chunks is more digestible and can be incorporated to fit around work-based tasks or other learning activities. Developing learning content into manageable chunks, i.e. 'learning objects', allows the content to be delivered and re-used with less re-development costs incurred than with traditional methods (Urdan & Weggen; 2000). For example, a module's introductory session at WMG can consist of several different lesson overviews, corresponding to several different learning objects. Individually these learning objects can be used at

the start of each of their respective lesson. The value of a learning object is increased each time it is reused, because this produces cost-savings by avoiding further effort and time on the development of its subject matter. The modular approach to learning helps to satisfy immediate learning needs by presenting content in bite-sized amounts. This provides 'just-enough' content for the desire for JIT learning, by assisting in the retention and recall of the necessary content for specific skills, knowledge or a combination of both. This was discussed in section 4.2.4. Learning objects also facilitate a competency-based learning approach by matching the object's meta-data with individual's competency gaps (Brennan et al, 2001). Thus, learning objects are utilised to produce and structure learning content efficiently, and tailor relevant content to the individual's specific requirements. Hence, the development of learning objects provides flexible, modular, customised learning activities, as well as content that is reusable and manageable. The utilisation of learning objects was one of the recommendations made by the author to Company X and WMG which was reported in submission 5.

The project work carried out to investigate these latter contributing areas of knowledge has provided a better understanding for developing improved e-learning content for engineers and enhancing their learning and working environments. Consequently, these areas have helped to reinforce factors in the e-learning framework during its development, and so strengthen the innovation. Even though the framework is aimed at assisting e-learning developments for practising engineers in industry and engineering students in academia, there is no reason why the framework can not be utilised to assist other fields of e-learning development. Section 7.2 in the concluding chapter discusses recommendations for further work which identifies other areas of application for the framework. Hence, there is scope to utilise the framework for a wider audience, and so it has the potential to be a generic functional e-learning tool-kit.

7.0 CONCLUSIONS & RECOMMENDED FURTHER WORK

7.1 Conclusions

Modern engineering activities are increasingly becoming more distributed, collaborative and multi-disciplined in both industry and academia, which requires organisations to consider alternative ways to inform and educate their employees and students. The engineering organisations investigated recognised this, and so have planned, developed and implemented in varying degrees, a more flexible technology-based learning approach for their current training, informing and teaching practices. These practices need to be continuous processes rather than one-time activities, to enable professional and student engineers to update and expand their knowledge and skills, and thereby maintain their value in the marketplace.

E-learning was researched as a possible solution for addressing these engineering requirements. The opportunity e-learning presents is to enable a more flexible learning approach than traditional instructor-led learning by providing access to a variety of up-to-date learning content, anywhere and at any time. E-learning's flexibility is also seen as its ability to blend standard and customised, guided and self-directed learning content, and cater for individual and collaborative VLEs. Table 7-1 provides a list of the main comparisons between traditional instructor-led learning and e-learning, which have been emphasised throughout the research.

Table 7-1: Traditional Learning & E-learning Comparisons (updated James-Gordon, 2001)

Traditional Learning	E-learning
4 Year Engineering Degree	Continuous Life-long Learning
Standard Content	Standard & Customised Modular Content
Concentrated Learning	Distributed Learning
Presented & Instructor-directed	Guided & Self-directed
Limited Media	Interactive Appropriate Multimedia
Structured Just-in-Case Content	Combining Immediate & Structure Content
Isolated Individual Environments	Collaborative Global Environments
Classroom-based	Virtual Learning Environments
Knowledge-based Academia	Blended Knowledge-based & Skills-based

The research revealed gaps both in the existing literature and working practices, regarding the e-learning needs of engineers and in current approaches that provide a holistic e-learning solution that integrates different factors to meet these needs. This was guided by the insights and applications of learning processes of both practising engineers in industry and engineering students in academia. The investigations focused on various learning factors that enable, support and enhance e-learning in product-development and self-development engineering environments. This involved examining enabling technologies, learning philosophies, delivery mechanisms and management facilities. These areas were poorly represented as integrated categories in the literature and were limited in providing e-learning solutions for engineers. Furthermore, existing e-learning research and developments were found to be fragmented and mainly emanated from educationalists' or technologists' fields, with little evidence on how the different learning factors in these fields integrated or complemented each other. Additionally, the research established that technology-led solutions had often guided and controlled e-learning developments and this was experienced with the academic case study.

The main objective of the research was to create an e-learning mechanism to group and appropriately integrate various learning factors, to effectively produce e-learning activities in engineering development environments. Designing, developing and implementing e-learning activities were found to be complex processes, and so the proposed mechanism needed to be able to cope with the following issues and be updated as the research advanced:

- Changing and varied content for the learning required.
- Categorising and then prioritising disparate learning factors.
- Dispersed and local learners with different or similar knowledge and skill-sets.
- Independent and collaborative learning environments.
- Different levels of support required.

- Keeping abreast of the advances in technology but not being technology-led.

A framework was developed as the e-learning mechanism because it can accommodate these diverse issues. Avison & Fitzgerald (1995) point out that a framework does not need to be fully defined in its construction and can evolve by improving or changing. Also framework is more flexible than a methodology or model, as it does not have to operate within set boundaries or in fixed sequences. Non-comparable learning factors can be grouped, selected, linked and ordered differently depending on the requirements, and not all the factors need to be considered. The rationale for adopting a framework was discussed in section 3.1 and re-iterated in section 6.2. Thus, the main research innovation is the creation of the e-learning framework which provides the following functionality:

- **E-learning solutions which are not technology-led.** Enabling technologies need to be designed to support the learning activities. The technologies are aligned to the content and its requirements as well as to the appropriate learning factors within the philosophy, delivery and management categories.
- **A wrapper where categories contain disparate learning factors.** Figure 3-1 illustrates the structure of the framework's categories and the learning factors grouped within them.
- **Linking learning factors to help satisfy learning requirements.** Section 3.4 provides guidelines to help steer e-learning providers through the framework by selecting and sequencing appropriate learning factors to develop e-learning activities.
- **Specific e-learning solutions for engineers in development environments.** Different models in the framework can be created to satisfy different e-learning applications, which are dependent on the learning requirements. Table B-1 in appendix B illustrates the different engineering e-learning applications investigated.

Synthesising the e-learning framework has helped to address the research question posed in section 1.1.3 – ***"How can e-learning provide effective learning for engineers in development environments?"*** The underlying sub-questions that this raised were addressed in five research projects. These separate, but mutually supporting projects were documented in respective EngD submissions. The following list summaries the main areas of the project work undertaken:

1) **Exploring learning methods and preferred learning styles in engineering environments:** These investigations were carried out to help understand standard practices and identify areas where e-learning can replace or complement existing learning methods. Learning styles preferences of engineers were examined to ascertain if these were aligned to the current learning methods. A survey established that engineers are experiential learners and a second survey discovered that engineers have a strong visual learning preference. Therefore, experiential and visual methods are important factors to consider when developing learning activities for engineers. TBL was investigated as a solution to accommodate engineers' learning style preferences, and to provide a self-directed, customisable and collaborative learning environment.

2) **Examining the available technologies to enable, support and enhance learning:** Current TBL tools and techniques were investigated to establish their capabilities for enabling, supporting and/or enhancing the design, development, delivery and management of e-learning content. The supporting 'hard' learning technologies examined physical tools such as computer-based and Web-based tools. Web technologies were of particular interest to this research due to their wide reach and interactive impact on the modern working and learning environments. 'Soft' learning technologies examined non-tangible technologies such as instructional principles. However, more controversial enhancing 'soft' technologies were also investigated, such as smart drugs, in order to illustrate the various facets of technology, but they

were beyond the scope of the main research. Thus, TBL was found to be too broad for this research and so e-learning narrowed this down to electronic-based learning technologies, which embraced CBL and WBL.

3) **Investigating marketing considerations from the WBL providers' viewpoint:** Various WBL providers were investigated to identify the available WBL products offered and the different marketing approaches these providers took. These WBL providers were found to supply academic or corporate organisations with WBL content, technology or services, or a combination of these. Subsequently these organisations then provided their own customised e-learning solutions for their departments, employees, students, or even other organisations. Determining the marketing considerations from the WBL providers' viewpoint provided an understanding of what can, and can not, be achieved within the environmental constraints and the fragmented e-learning market.

4) **Developing an e-learning framework:** Previous project work and findings were consolidated to develop an e-learning framework to assist e-learning providers through the maze of disparate learning factors to develop relevant e-learning activities. The various learning factors researched were grouped according to their function under philosophy, delivery, management or technology categories in the framework, as shown in figure 3-1. This grouping helped to simplify the selecting, linking and ordering of the learning factors and fit the appropriate technology to them. CSFs were also produced to provide a complementary business perspective in developing e-learning content. These CSFs relate to certain learning factors in the framework and are shown in figure 5-1.

5) **Studying practical engineering e-learning applications:** The e-learning environments of three engineering organisations were investigated as case studies to help test validate areas of the framework - two from industry and one from academia.

These case studies were not meant to be conclusive but illustrated the diversity of engineering e-learning environments. Comparisons were made between the environments, which incorporated the different learning requirements and effects. The academic case study helped test and verify the CSFs, because it was in the midst of its e-learning development. Whereas one of the industrial case studies had yet to gain full management support to proceed with its e-learning development and the other had already developed and implemented its e-learning environment. Thus, the framework's learning factors and CSFs were tested and refined accordingly.

The combination of these research projects helped with the development of the e-learning framework and CSFs. The contributing areas of knowledge, which were a consequence of the project work, helped to provide deeper understanding in areas of the e-learning development. Section 6.3 discussed these areas of knowledge, and these are summarised as:

- **Presentation of learning content.** The research discovered the preferred visual learning style of engineers, and so the importance of incorporating visual techniques when developing e-learning activities and designing the e-learning user interface.
- **Provision of experiential learning activities.** Engineers were found to work and learn experientially. They adopt each of the activist, reflector, theorist and pragmatist learning styles and their characteristics depending on where they are in the product-development or self-development stage, and then repeat these if required. Thus, the different stages of experiential learning need to be considered when developing e-learning activities for engineers.
- **Provision of self-directed, discovery learning experiences.** Discovery learning is important for engineers due to the nature of work in their development environments, where they perform tasks individually and/ or collaboratively to optimise an

engineering solution. Thus, e-learning activities need to contain exploratory, problem-solving learning features within the learning environments.

- **Incorporation of appropriate assessments.** Pre and post-assessments not only measure learners' levels of knowledge, before and after an e-learning activity, but they also measure their change in performance. Electronic assessments can assist instructors track and test learners' progress. Additionally, self-directed learners can monitor their own work. The results from assessments can lead to future e-learning activities being customised to suit the learners' capabilities.

- **Combination of guided & self-directed modes.** Different learning modes are required in a learning activity depending on learners' experience and level of support required. Different types of support reinforce or complement learning activities. For example, providing online learning information resources, electronic guides, online peer assistance, and further emailed explanations, within problem-solving activities. This helps to integrate direction and guidance with discovery learning activities

- **Integration of relevant type, level & range of learning content.** Professional and student engineers were found to combine different content type, level and range to help provide wider, transferable, relevant competencies for their organisation and/or themselves. Integrating these different content characteristics provides variations from structured, generic, content-specific, knowledge-based content to immediate, customised, learner-specific, skills-based content.

- **Provision of manageable learning objects.** Learning content broken down into smaller amounts is more manageable for Instructional Developers developing a learning activity, as well as more digestible for learners. Learning objects allow the content to be re-used, structured and customised more easily to satisfy the learning requirements.

These points identify important areas to be considered when developing e-learning content for engineers in product-development and self-development environments. These areas have contributed to learning factors within the e-learning framework. Thus, the construction of the e-learning framework has built from, added to, and consolidated the various learning factors investigated in this research.

In summary, the development of the e-learning framework provides a mechanism to facilitate effective e-learning in engineering development environments. The framework structures disparate learning factors into philosophy, technology, delivery and management categories, depending on their functionality, and links and orders these factors to suit different learning requirements. The framework acts as a tool-kit for e-learning providers to help guide them through the maze of learning factor options and decisions to generate relevant e-learning activities. The CSFs additionally devised, which complements the framework, provide a business perspective to the e-learning development and acts as an action-plan for managers instigating an e-learning programme. The research has shown that e-learning can enable, support and enhance continuous learning for engineers, and that the framework provides the foundation on which to build effective e-learning content.

The next section outlines further project work that can be undertaken from additional applications of the e-learning framework, and for developing richer engineering e-learning content.

7.2 Recommendations for Further Work

There are two opportunities identified by the author for carrying out additional work to help refine and develop the research further. One area is to utilise the e-learning framework in further applications, and the other is to investigate developing richer engineering e-learning content. These two areas are described below:

1) **Further applications of the e-learning framework.** This can provides additional, advance, different or complete applications of the framework:

   - Investigate 'additional' organisations in academia and industry with e-learning environments already established to reinforce other factors developed in the framework. For example, to provide a deeper understanding of security and administrative issues in e-learning.
   - Obtain Senior Management support at Company X, and 'advance' their engineering e-learning environment by developing their proposed portal design with their recommended engineering content. Then, assist with the management of the full e-learning implementation.
   - Apply the framework to 'different' environments of engineering or other industries, as the industrial case studies focused on product-development environments. Manufacturing or civil engineering environments can be useful additional case studies undertaken for comparisons.
   - Utilise the framework and CSFs from start to finish across a 'complete' e-learning programme.

2) **Developing richer engineering e-learning content.** The following areas for further research can provide a better understanding and direction of future engineering skills, knowledge & experiences:

- Further investigation into using design visualisation techniques can assist the learning environment for engineers. Specific electronic technologies and the practicality of using VR in industry and academia can provide a non-threatening and safe environment for training and learning to be carried out, as briefly reported in submission 2. This investigation can contribute to the technology and delivery categories of the framework.

- Determine how learning experiences can be kept up-to-date. Engineering content can incorporate new skills developed in industry being fed-back to be incorporated into academia. For example, incorporating work-based projects that use industry specific and standard engineering processes not often taught in academia. Two examples being (i) specific testing procedures for prototype builds and (ii) Design Failure Mode Effect Analysis (DFMEA) auditing, which is a methodology used for assessing potential risks to the design integrity early in the development cycle. This investigation can be part of the learning content material of the framework.

- Examine mobile learning using technology that is portable, individual and adaptable as a solution to keep the engineers that are field-based up-to-date with required information. This investigation can contribute to the technology and delivery categories of the framework.

- Investigate how the future engineering students can learn without having practical experience of using machine tools in academia, due to the increasing health & safety restrictions. Can VLEs be established in academia to equip engineers with the practical skills they need for industry, or at least gain an understanding? Additionally, if manufacturing continues to be outsourced abroad, how do engineers in development environments gain a real appreciation of manufacturing processes and capabilities, e.g. DFM and DFA experience? Will engineers be required to liaise with manufacturing suppliers abroad, and so require additional collaboration techniques incorporated into their modern teaching and learning practices? These investigations can contribute to the content, technology and delivery categories of the framework. However, providing learning experiences within VLEs, and using VR technology, may be the only way in which engineers gain practical skills and experiences in the future.

From the application of these further research recommendations, the e-learning framework can be updated to supply richer learning activities for providing and maintaining effective e-learning in engineering development environments.

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THE UNIVERSITY OF WARWICK

School of Engineering

A Framework to Facilitate Effective E-Learning in Engineering Development Environments

EXECUTIVE SUMMARY: APPENDICES

APPENDIX A: PAPERS PUBLISHED BY THE AUTHOR

APPENDIX B: E-LEARNING FRAMEWORK APPLICATION

WMG
MANAGEMENT·SYSTEMS·TECHNOLOGY

APPENDIX A

PAPERS PUBLISHED BY THE AUTHOR

Appendix A provides a copy of each paper published by the author during the Engineering Doctorate registration with the assistance of her co-authors. Jay Bal ensured that the content had academic rigour on all the papers. Andy Young ensured that the marketing content was valid on the marketing paper in appendix A4, as this was a disciple that the author initially had limited working experience in. Each paper published assisted in validating the author's research in a methodical manner. Part of the material for writing the papers was extracted from the EngD submissions or post-module work, and assisted in summarising the main issues investigated in the research. The papers presented at the ED-MEDIA 2003 Conference also provided valuable feedback to the author from a wider audience that were expert in the e-learning field. The poster presentation with the paper in appendix B6 attracted interest. The author believes that this was because she presented an application to e-learning, whilst the other delegates at the conference were either educationalists presenting learning philosophies or computer scientists presenting the capabilities of the technology.

In summary, six papers were published external to WMG and in addition to the EngD annual conferences, and they consisted of four journal papers, a presentation conference paper, and a poster presentation paper. Full reference information has been provided with each paper, for examining the quality or suitability of the journal, if necessary.

Appendix A1

PAPER 1

Learning Style Preferences of Engineers in Automotive Design

James-Gordon Y E; Bal J; (2001)
Journal of Workplace Learning;
Vol.13, No.6, pp.239-245;
MCB University Press, Bradford, UK.

Learning Style Preferences of Engineers in Automotive Design

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Keywords

Learning styles, Learning preferences, Learning cycle, Engineering Design.

Abstract

An investigation was conducted in the Design Department of a medium-sized automotive company to establish engineers' preferred learning styles. This was achieved by using two proven questionnaires followed by statistical analysis methods.

The evidence showed that the engineers investigated have a significant *visual* learning style preference. This means that their learning is more effective by using diagrams, sketches, photographs, schematics, flow charts, pictures, videos, computer graphics, and demonstrations in training programmes and in their everyday working environment. The present computer-aided design (CAD) training in the company does incorporate some of these visual techniques and so does satisfy the engineers' visual learning style preference. Evidence also suggested that there is not a need to have different training and learning methods for Design Engineers or managerial engineers such as Project Engineers and Team Leaders.

The company investigated was recommended to incorporate visual techniques when developing further training material and learning aids, in order to create an effective learning environment for their engineers.

Introduction

Learning styles describe the attitudes and behaviours that determine the preferred way of learning of an individual. People vary not just in their learning skills but also in their learning styles (Felder, 1996). The objectives of this investigation were to establish the following:

- Do engineers have different learning characteristics than the rest of the professional population, and if so what are their preferred styles of learning?
- Does the present computer-aided design (CAD) training available satisfy the engineers' learning style preferences?
- Do Design Engineers have different learning characteristics than managerial engineers, such as Project Engineers and Team Leaders?

From reviewing the literature, the characteristics of each learning style are summarised below (Felder, 1996; Honey & Mumford, 1992; Kolb, 1984; Senge, 1992):

- **Activists or Active Learners** like to try out new experiences and tend to be open-minded people. Problems are often tackled by brainstorming. They thrive on new experiences but find implementation and consolidation dull. They are gregarious people and prefer working in groups.
- **Reflectors or Reflective Learners** observe and ponder experiences. Data is collected and analysed thoroughly about experiences before any conclusion is made. In meetings they adopt a low profile, listening to others before commenting. Generally they tend to be cautious people who prefer to work alone.
- **Theorists** integrate observed experiences, thinking problems through methodically. They feel uncomfortable with subjective

opinions and ambiguity, and prefer establishing logical theories from facts. They tend to be analytical people and perfectionists, fitting things into rational schemes.

- **Pragmatists** like to put theories into practice. They prefer producing plans before promptly getting on with things. Pragmatists are the kind of people who are keen to try out new skills learnt on courses. They are practical people who like solving problems and tend to be impatient with slow and inconclusive discussions.

- **Sensing Learners** tend to be patient and careful with detailed work. They are good at learning facts and often like solving problem by well-established methods. Sensors are inclined to be practical and like hands-on work. They dislike complications and surprises.

- **Intuitive Learners** prefer discovering possibilities and relationships. They are comfortable with new concepts and are more innovative than others. Intuitors dislike routine calculations that require memorising.

- **Visual Learners** remember best by what they see. They absorb information more effectively from pictures, diagrams, films and demonstrations. They prefer their work to be colour coded for categorising purposes, and highlighted words and sentences for clarity.

- **Verbal Learners** tend to learn best from written and spoken explanations. They understand something better by talking to peers. They are comfortable reading books and manuals to absorb information.

- **Sequential Learners** tend to gain understanding in logical steps. They prefer to methodically go through calculations until solutions are found. They tend to like procedures to follow.

- **Global Learners** tend to learn randomly without initially seeing the connections, and then suddenly they are enlightened. They tend to solve complicated problems quickly but can have difficulty explaining the steps. Once the whole picture emerges for them, they will find new ways of accomplishing tasks.

The company used to research into engineers' learning style preferences was a medium-sized automotive company (>50 employees <250). All the engineers at this company utilise CAD software for 3D design, development, optimisation, data management, and detailing. Traditional instructor-led courses are adequate for teaching CAD and other engineering skills. However, there is a need to develop customised training material that can be accessed when the engineer needs to learn new skills, and not wait until the next instructor-led classroom course. As the responsibility is put on all engineers at the company to keep updated and refreshed with engineering knowledge and skills, what techniques can be used to make their learning more effective?

Methodology

In order to examine the objectives primary data was collected using questionnaires in order to investigate the engineers' various learning style preferences. There were two questionnaires selected after careful research and discussions. One was an established questionnaire devised by Honey & Mumford (1992), referred to as *questionnaire one* in this paper. The other was a prototype version, developed from the latter by Felder (1996) and referred to as *questionnaire two* in this paper.

Questionnaire one asked 80 questions (20 for each of the activist, reflector, theorist and pragmatist learning styles). *Questionnaire two* asked 44 questions (11 for each learning style pair – active/reflective, sensing/intuitive, visual/verbal and sequential/global).

Questionnaire two was used to complement *questionnaire one,* as the author (YJ-G) was not satisfied with the balance of *questionnaire one.* Honey & Mumford's *questionnaire one* seemed to categorise people by having either a strong to low preference of the activist, reflector, theorist and pragmatist learning styles. Engineers due to their nature and skill-sets will cycle through many learning styles and adopt their characteristics when determining a design solution. Felder's *questionnaire two* had a more balanced approach, as the learning styles were paired. A high preference for a particular learning style indicated a low preference for its corresponding pair. There was also an interest in the verbal/visual and sequential/global learning style pairs offered in Felder's questionnaire.

As there were no right or wrong answers to either of the questionnaires, assurance was given to the engineers that their results were for research purposes only and would not be used for any kind of assessment of them. The engineer needed to consider each question carefully and to what extent that question applied to him or her. *Questionnaire one* required a tick ☑ for sentences that were agreed with and a cross ☒ for sentences disagreed with. *Questionnaire two* required (a) or (b) circled if the engineer was in more of an agreement with that sentence. Both questionnaires needed all of the questions answered, even if the answers given were borderline responses.

Both questionnaires were given to all 45 engineers in the Design Department in the company, of which 42 gave replies: 27 Design Engineers and 15 Project Engineers & Team Leaders. Both questionnaires were left with each engineer for a period of two weeks before returning to the company to collect the data.

After the questionnaires were collected, the data was manually entered into each of the respective score sheets for each engineer. Each column was then totalled and the results were tabulated for ***all the engineers***. The results were also sub-divided into *Design Engineers* only and *Project Engineers & Team Leaders* for comparisons in the data analysis.

Questionnaire Interpretation

The population data collection for *questionnaire one* was based on a *Population* of 3500 scores of professional people working in industry and commerce in the UK (Honey & Mumford, 1992), illustrated in *Table 1.*

As both the selected questionnaires had the population Mean given for each learning style, it suggested that the data should be representation and so tend to form a Normal distribution.

From scoring the results of *questionnaire two*, the engineer could compare himself or herself to the scale, illustrated in *Table 2* (Felder, 1996) and described as follows:

- If the score is between –3 and +3, then the person is *well balanced* on the two dimensions of the scale (Mean is 0).
- If the score is between –5 and –7, or 5 and 7, then the person has *a moderate preference* for one dimension of the scale and will learn more easily in a teaching environment that favours that dimension.
- If the score is between -9 and -11, or 9 and 11, then the person has *a very strong preference* for one dimension of the scale. According to Felder (1996), this may produce difficulty within an environment that does not support that learning preference for the individual.

Table 1: Population Scoring Results Interpreted for Questionnaire One (Honey & Mumford, 1992)

	Very strong preference	*Strong preference*	*Moderate preference*	*Low preference*	*Very low preference*
Activist	13 - 20	11 - 12	7 - 10 (Mean 9.3)	4 - 6	0 - 3
Reflector	18 - 20	15 - 17	12 - 14 (Mean 13.6)	9 - 11	0 - 8
Theorist	16 - 20	14 - 15	11 - 13 (Mean 12.5)	8 - 10	0 - 7
Pragmatist	17 - 20	15 - 16	12 - 14 (Mean 13.7)	9 - 11	0 - 8

Table 2: Population Scoring Results Interpreted for Questionnaire Two (Felder, 1996)

	Very strong preference	*Moderate preference*	*Well balanced (Mean=0)*	*Moderate preference*	*Very strong preference*	
Active	-11 to -9	-7 to -5	-3 to 3	5 to 7	9 to 11	**Reflective**
Sensing	-11 to -9	-7 to -5	-3 to 3	5 to 7	9 to 11	**Intuitive**
Visual	-11 to -9	-7 to -5	-3 to 3	5 to 7	9 to 11	**Verbal**
Sequential	-11 to -9	-7 to -5	-3 to 3	5 to 7	9 to 11	**Global**

Quality of Results

All the engineers scoring results are collated into the learning preference ranges as seen in *Tables 3 & 4,* from *questionnaire one* and *questionnaire two* respectively. The 42 out of 45 replies collected, provides a good response to the survey. By inspecting the learning styles' results, the quality of the data and distribution features can be observed.

[Complete data analysis and statistical calculations, including graphical representation of the data collected, can be obtained from the author (YJ-G) on request.]

The Activist and Reflector learning style scores from *questionnaire one* should compare to the Active/ Reflective scores on questionnaire two. The very strong learning preferences range for Activist is 13 to 20 and the Active learner is –9 to –11. The two same *Design Engineers* do correspond to this. However, the Reflector scores seemed to be marked much higher than the corresponding Reflective learning style scores for *all the engineers*.

The scores of the engineers learning styles are representative, being within the professional people Population scores. As the outliers in the learning styles are feasible preferences, this tends to suggest that these learning style distributions are skewed or that error has crept in. The reasons for error may have been because incorrect answers were given due to ambiguity of sentences: During the period the questionnaires were left at the company, many engineers did contact the author (YJ-G) and complained that *questionnaire two* had a few ambiguous and controversial sentences, e.g.

"I would rather be considered:
(a) realistic or (b) innovative"

This question annoyed many engineers as they considered themselves to be both (a) and (b), and did not want to choose one answer over the other.

If they chose (a) realistic, did that mean they were not innovative and visa versa? Engineers by their very nature will be innovative during the initial design stages and realistic when it comes to selecting materials and manufacturing processes for their design. These design activities are typical of the engineers at the company.

The Reflector, Theorist and Pragmatist scores are skewed towards the strong learning style preferences. The Visual/Verbal learning style pair is bias towards the Visual end, indicating this is a very strong learning preference for all the engineers.

Table 3: All the Engineers Scoring Results for Questionnaire One

	Very strong preference	*Strong preference*	*Moderate preference*	*Low preference*	*Very low preference*
(score range) **Activist**	(13 – 20) **5**	(11 – 12) **7**	(7 – 10) **14**	(4 – 6) **11**	(0 – 3) **5**
Reflector	(18 – 20) **10**	(15 – 17) **16**	(12 – 14) **9**	(9 – 11) **4**	(0 – 8) **3**
Theorist	(16 – 20) **10**	(14 – 15) **11**	(11 – 13) **13**	(8 – 10) **6**	(0 – 7) **2**
Pragmatist	(17 – 20) **6**	(15 – 16) **11**	(12 – 14) **17**	(9 – 11) **6**	(0 – 8) **2**

Table 4: All the Engineers Scoring Results for Questionnaire Two

	Very strong preference (-11 to –9)	*Moderate preference* (-7 to –5)	*Well balanced* *(Mean=0)* (-3 to 3)	*Moderate preference* (5 to 7)	*Very strong preference* (9 to 11)	
Active	**2**	**8**	**25**	**7**	**0**	**Reflective**
Sensing	**3**	**9**	**22**	**8**	**0**	**Intuitive**
Visual	**20**	**17**	**5**	**0**	**0**	**Verbal**
Sequential	**1**	**3**	**28**	**8**	**2**	**Global**

Experimentation of Results

Test to establish if the Mean of each learning style for all the engineers at the company was significantly different or not from that of the Population (professional people working in industry and commerce in the UK): The statistical calculations used the *student's t-test* method, as the sample size was only 42. Given the evidence available, the significance test calculations indicated that for the Visual/Verbal learning style pairs there was a highly significant difference between the Mean score for *all the engineers* and the Mean score for the *Population* (99.9% confidence level). For other learning styles, the evidence suggested, with 95% confidence, there was not a significant difference between the Means. This can be seen on the radar diagrams in *Figures 5 & 6.*

Figure 5: Learning Style Means for the Population and All the Engineers for Questionnaire One

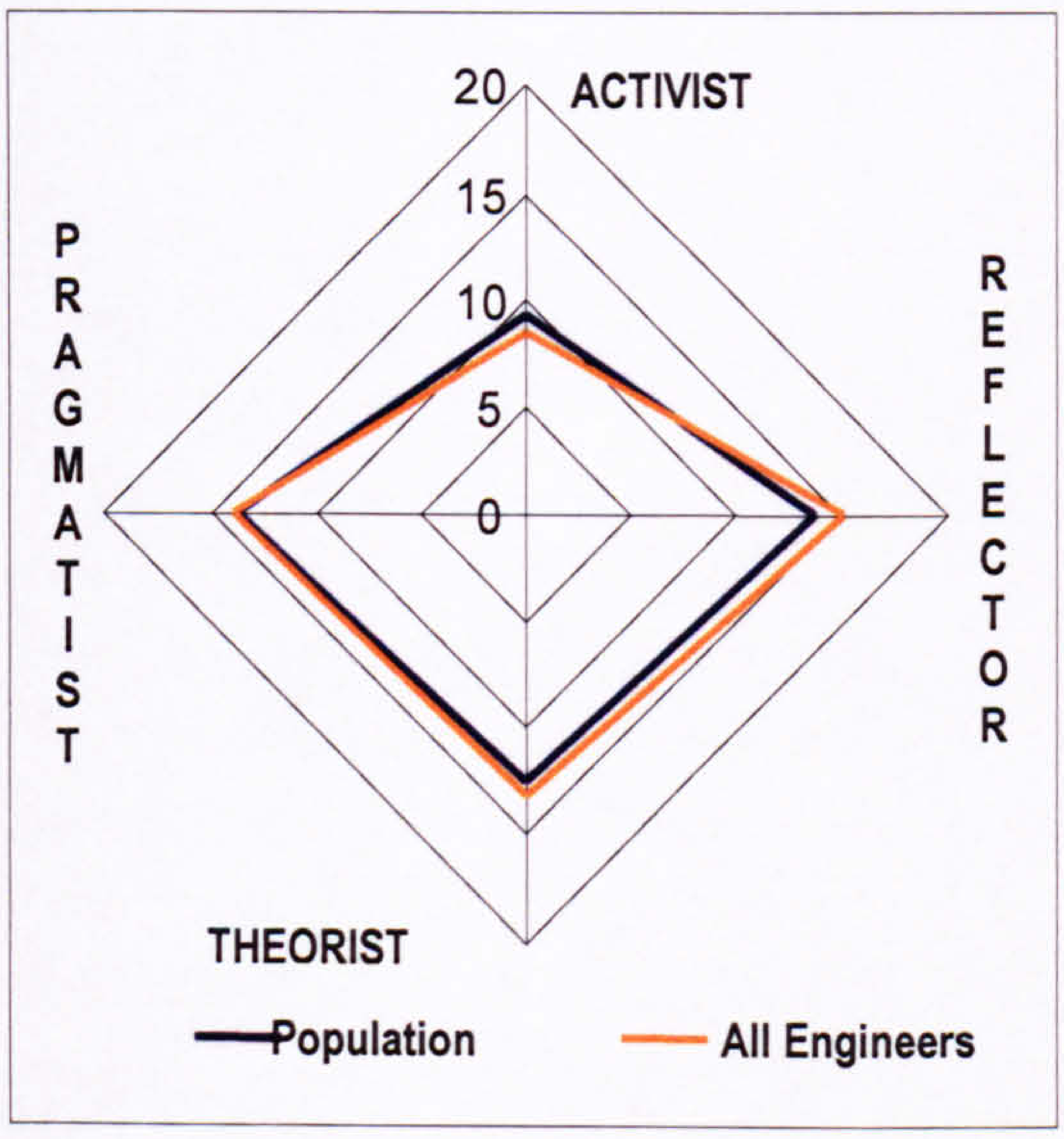
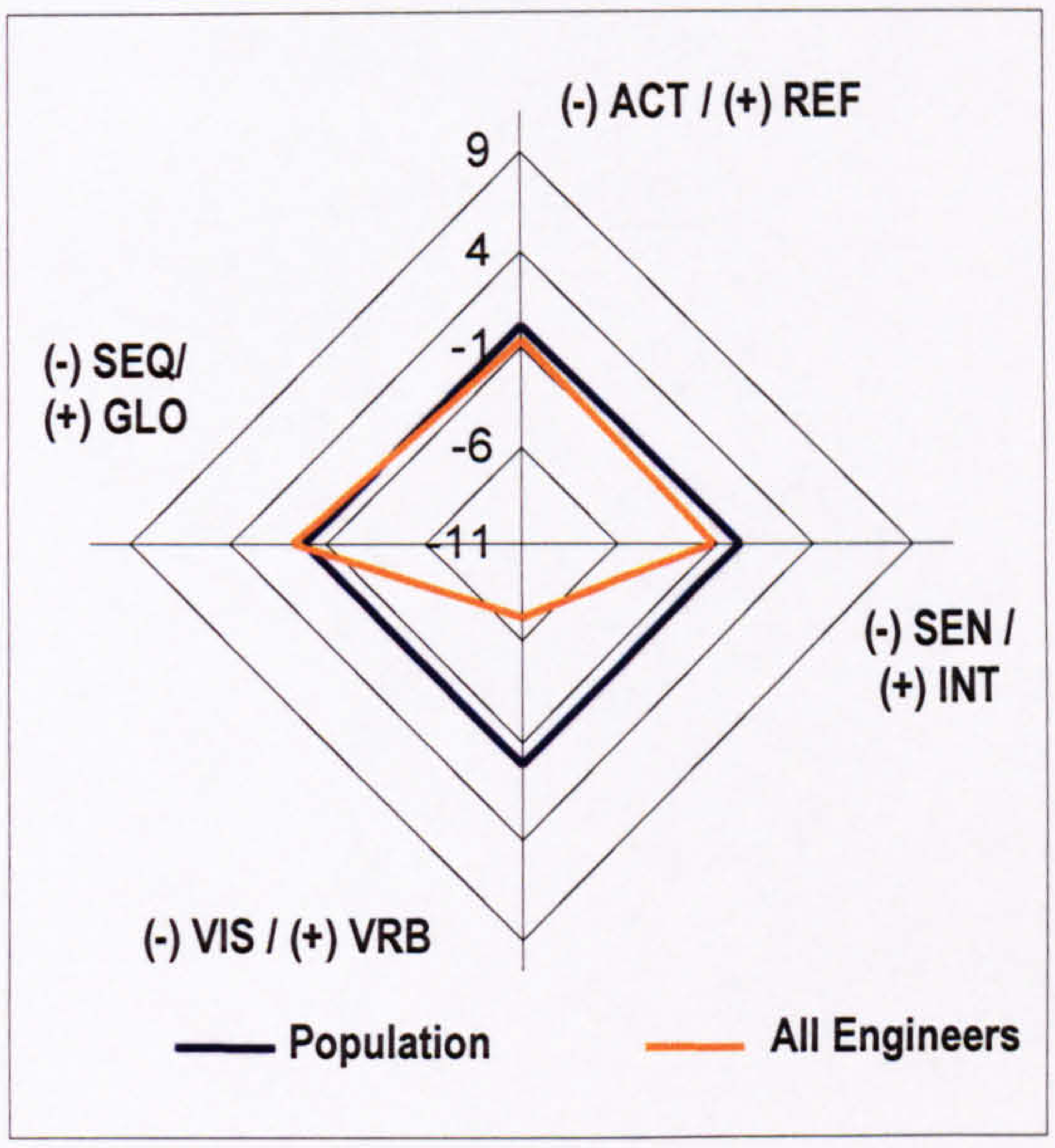


Figure 6: Learning Style Means for the Population and All the Engineers for Questionnaire Two



Test to establish if the Mean of each of the learning styles for the Design Engineers was significantly different or not from the Project Engineers & Team Leaders: The statistical calculations used again the *student's t-test* method. From the significance test calculations, the evidence indicated, with 95% confidence, that there was not a significant difference between *Design Engineers* Mean score and the *Project Engineers & Team Leaders* Mean score for all the learning styles. This can be seen on the radar diagrams in *Figures 7 & 8.*

Figure 7: Learning Style Means of Design Engineers and Project Engineers + Team Leaders for Questionnaire One

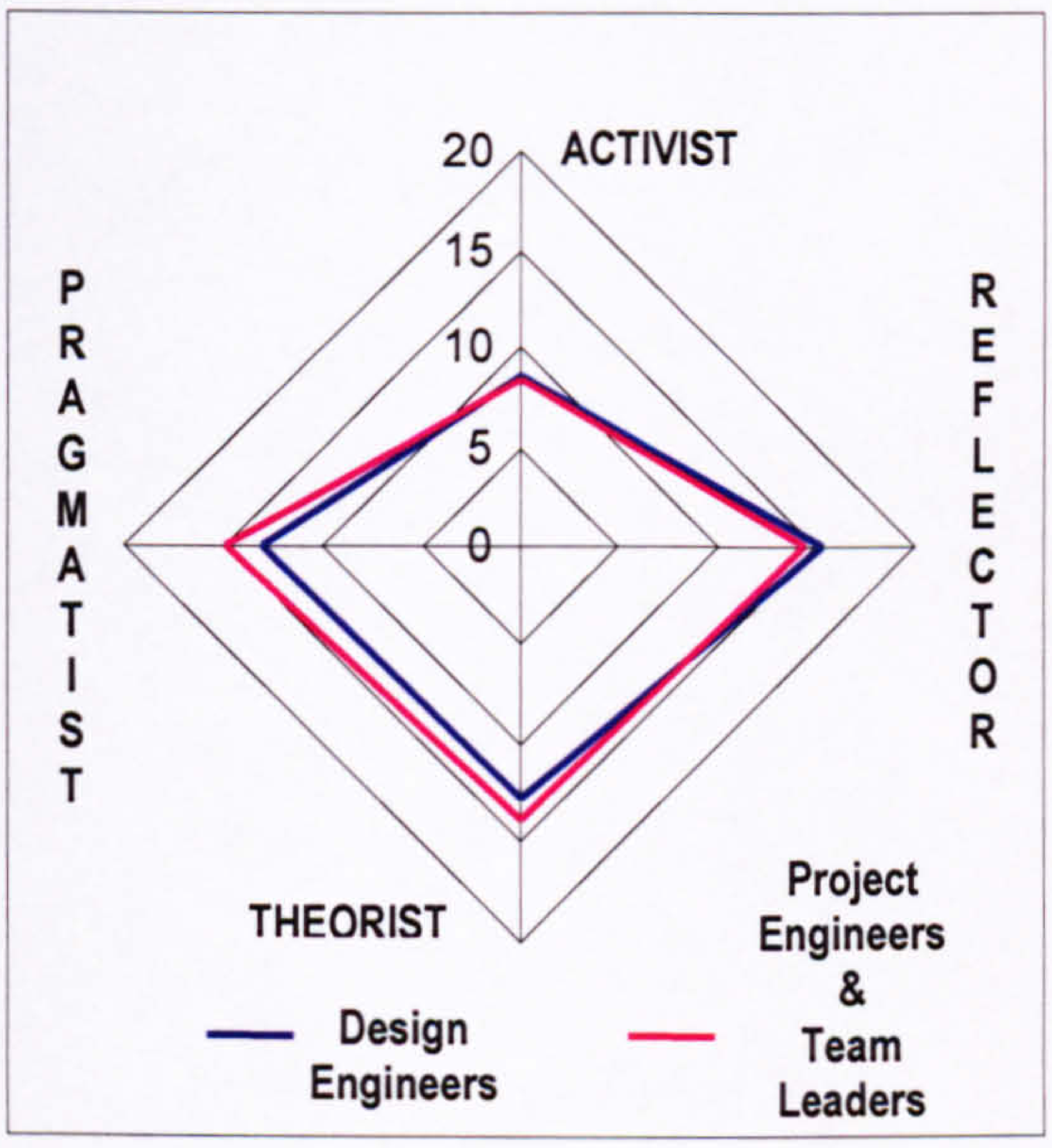
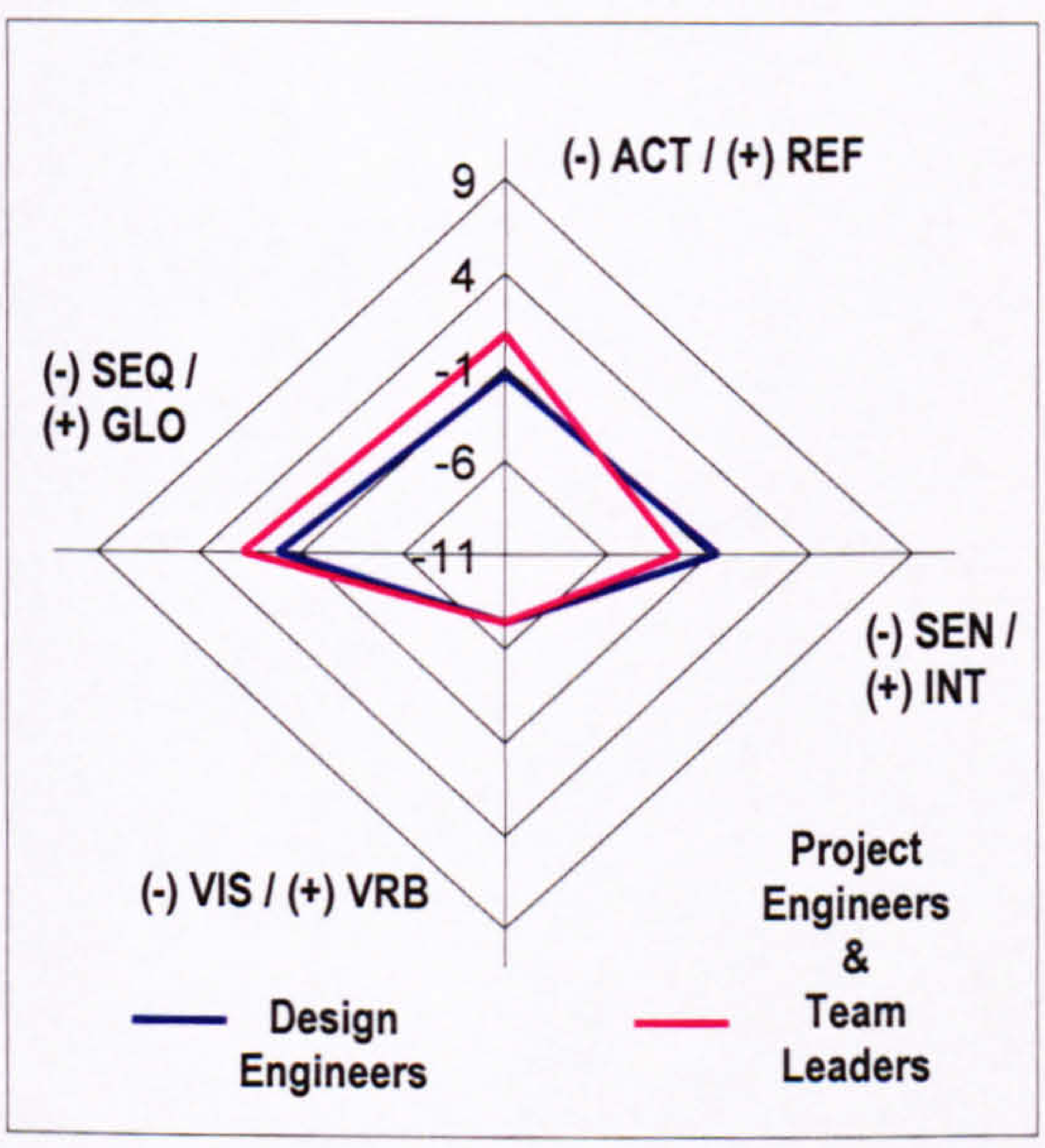


Figure 8: Learning Style Means of Design Engineers and Project Engineers + Team Leaders for Questionnaire Two



courses take advantage of these visual aids by using them in the training material. Demonstrations are given by the trainer to show the engineer what the CAD system is capable of, and then he or she works

Test to establish if the variance of each learning style for the Design Engineers was significantly different or not from the Project Engineers & Team Leaders: The statistical calculations used the *F-ratio test* method. From the available evidence and the significance test calculations, this suggested with 95% confidence, there was a significant difference between the variances of *Design Engineers* and the *Project Engineer & Team Leaders* for the Pragmatist and Sequential/Global learning styles. For other learning styles, the evidence suggested, with 95% confidence, there was not a significant difference between the variances. This can be seen on the radar diagrams in *Figures 7 & 8.*

Discussion of Results

The quantitative analyses carried out that used the standard statistical methods did produce reasonable results. However, due to the small sample tested, especially when comparing the *Design Engineers* with the managerial engineers, the results cannot be taken as conclusive. Nevertheless, evidence suggests that all of the engineers investigated are predominately visual learners. Hence, their learning is more effective from diagrams, sketches, photographs, schematics, flow charts, pictures, videos, computer graphics, and demonstrations. By the very nature of engineering design, these visual learning techniques are used everyday. Computer-aided design (CAD) is typical of this. CAD uses visual techniques such as icons to select commands, 3D parts are sketched, designed, assembled and analysed using coloured graphics, with more advanced animation and simulation techniques being incorporated into the CAD's functionality.

The present CAD training at the company does satisfy the engineers learning style preferences, as through a modelling example on the CAD system using the graphical interface, command icons, and visual computer-based help functions.

The *Design Engineers* after the CAD training *learn on the job*. According to Peter Senge (1992:23) *"the most powerful learning comes from direct experience"*. This is the preferred method of learning at the company, as engineers become more skilled, the more they use the CAD and still produced useful design work. A little more work time is given to the newly trained engineers to allow for their learning and familiarisation with the graphical user interface.

For all but the *visual* learning style, there is not a significant difference between the Means for *all the engineers* at the company and the *Population.* Engineers due to their nature will automatically cycle through all the learning styles and adopt their characteristics.

This iterative process, with reference to *questionnaire one,* is illustrated in *Figure 9,* and is fundamental to continuous learning. Experience gained adds to the engineer's own knowledge and skill-base, and provides corrective feedback, for example:

Stage 1: Run a finite element analysis (FEA) simulation on the CAD part to see where the high areas of stresses are, in order to prove that the design is feasible. This is an ***Activist*** learning style where learning is achieved by doing and experiencing.

Stage 2: Analyse FEA output results. This is a ***Reflector*** learning style where information is gathered before conclusions are reached.

Stage 3: Use the CAD software to methodically model a new part or modify the existing part, based on the FEA results. This is a ***Theorist*** learning style where the reason behind things, concepts and relationships are important for understanding.

Stage 4: Test the new CAD part in a CAD assembly, to see if part fits. Other design considerations to test include manufacturing and packaging implementations. This is a ***Pragmatist*** learning style by testing the practical application of what is learnt.

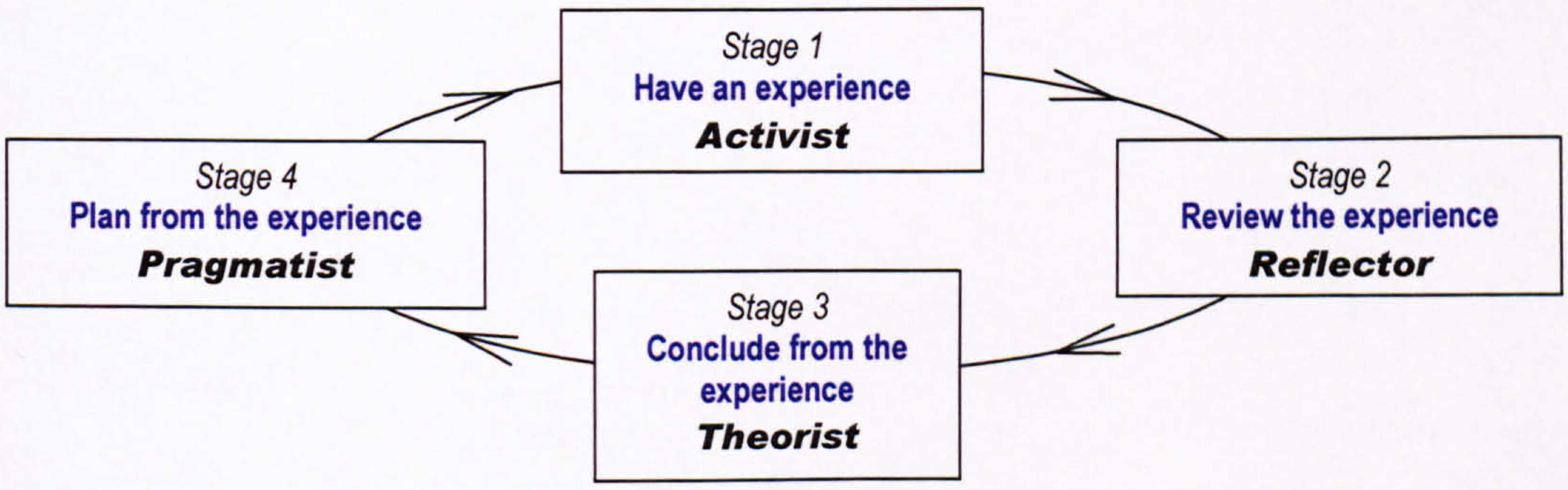


Figure 9: The Learning Cycle (Honey & Mumford, 1992; David Kolb, 1984

From the experience the author (Y J-G) has with the company, the organisation empowers all their engineers to take responsibility for their own learning and working practices. The *Design Engineers* have greater knowledge of their designs and developments than their *Team Leaders. Design Engineers* are self-motivated, adaptable and self-discipline working along side and collaborating with the *Project Engineers & Team Leader.*

Even though the sample sizes were small, the available evidence suggests, there is not a significant difference between the investigated *Design Engineers* Mean score and the *Project Engineers & Team Leaders.* All engineers are given the same learning opportunities and tools in the automotive company, so it is feasible that they would have similar Mean scores for their learning style preferences.

Given the available evidence and by inspecting the results for the Pragmatist learning style, the *Project Engineers & Team Leaders* investigated have less dispersed and higher scores than *Design Engineers* do. This is possibly because the *Team Leaders* produce project plans for the *Design Engineers* in their team, which is a Pragmatist learning style characteristic.

There are three extreme scores for the Sequential/ Global learning styles *Project Engineers & Team Leaders.* The *Project Engineer* who has a very strong Sequential learning style preference is the most experience *traditional* engineer at the company. He is the oldest engineer there, having a structured career route and being methodical in his design cycle. However, the other two *Team Leaders* have a very strong Global learning style.

In today's engineering climate that has technological advances to speed up design solutions and reduce product lead times, engineers, especially *Project Engineers & Team Leaders,* need to adopt more Global learning style characteristics.

Conclusions

The evidence concludes the following outcomes of the investigation at the automotive company:

- Engineers in the design environment have a very *visual* preferred style of learning. For all but the *visual* learning style, there is not a significant difference between the engineers at the company and the professional population.
- The present CAD training in the company does satisfy the engineers' learning style preferences, as it incorporates visual techniques and graphically represents the design.
- There is not a significant difference in the *Design Engineers* or managerial engineers such as *Project Engineers & Team Leaders* learning style preferences. Hence, there is no need to have different training and learning techniques for them.

As all the engineers investigated have predominately a *visual* learning style preference, the company was recommended to incorporate visual techniques when developing future customised training material, learning aids, and work-based programmes. The visual techniques can include diagrams, sketches, photographs, schematics, flow charts, pictures, videos, computer graphics, and demonstrations, in order to create an effective learning environment for the engineers.

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Appendix A2

PAPER 2

The Effects of Technology-based Learning on Design Engineers and the Organisation

James-Gordon Y E; Bal J; (2001)
Industrial & Commercial Training Journal;
Vol.33, No.5, pp.167-174;
MCB University Press, Bradford, UK.

The Effects of Technology-based Learning on Design Engineers & the Organisation

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Keywords

Technology-based learning, Computer-based learning, Web-based learning, Organisational learning, Design Engineering

Abstract

Technology-based learning (TBL) provides a flexible learning approach to support the knowledge and skills base within an organisation. TBL also creates an interesting learning environment to motivate continuous learning.

Emphasis is on the engineering design environment due to the continuous need for engineers to keep updated with current engineering information, knowledge and technologies. With the greater work demands placed on the engineer and less time to learn in, a more *self-directed* learning approach is required.

TBL tackles the increasing need for immediate learning and self-directed learning. By establishing an effective learning environment, the engineers can use their own initiative and take responsibility for their own training and learning requirements. This is beneficial to organisational learning as well as the individual's self-development. The effects of TBL on the Design Engineer and the organisation are investigated.

Word Count 4056

Introduction

Design Engineers have the continual need to keep up to date with current and new design information, knowledge and technologies, such as new design simulation tools, new prototype techniques, new materials and new manufacturing processes. Periodically, design skills or techniques require learning or renewing, such as with computer-aided design (CAD), finite element analysis (FEA), or product data management (PDM). Hence, technology is an important part in their everyday engineering design processes.

The objectives of this investigation were to identify the effects of technology-based learning (TBL) on engineers in a design environment and the organisation they work for.

TBL in engineering design can include any of the following for the engineer:

- Technology to increase design knowledge by its use to create a design solution, e.g. CAD or by *surfing* the Web to find design information.
- Technology to assist in the learning process to create new design skills, e.g. computer-based learning (CBL) or multimedia tools.
- Knowledge of the design technology increases with usage, e.g. the more the individual uses CAD, the more experience he or she becomes.
- Technology involves the 'know-how' in people, and sharing information and knowledge increases understanding (Petrovic et al, 1998).
- Technology to assist in the sharing of information with peers, e.g. Web tools including emailing facilities, conferencing, whiteboards, and discussion forums.

Effects of TBL on the Design Engineer

Besides technology being used in learning a new skill, increasing knowledge, and sharing information, the preferred learning style for the individual is also important for learning to be more effective. Engineers due to their nature will automatically cycle through all the learning styles and adopt their characteristics during the design and development of a product. This iterative process is fundamental for continuous learning and the design cycle.

David Kolb, who has been particularly influential in management education, developed the theory of experiential learning (Kolb, 1984, cited in Garratt, 1994). He described learning as following a cycle in which there are four areas:

- Concrete experiences
- Reflective observation
- Formulation of abstract concepts
- Testing concepts on new situations

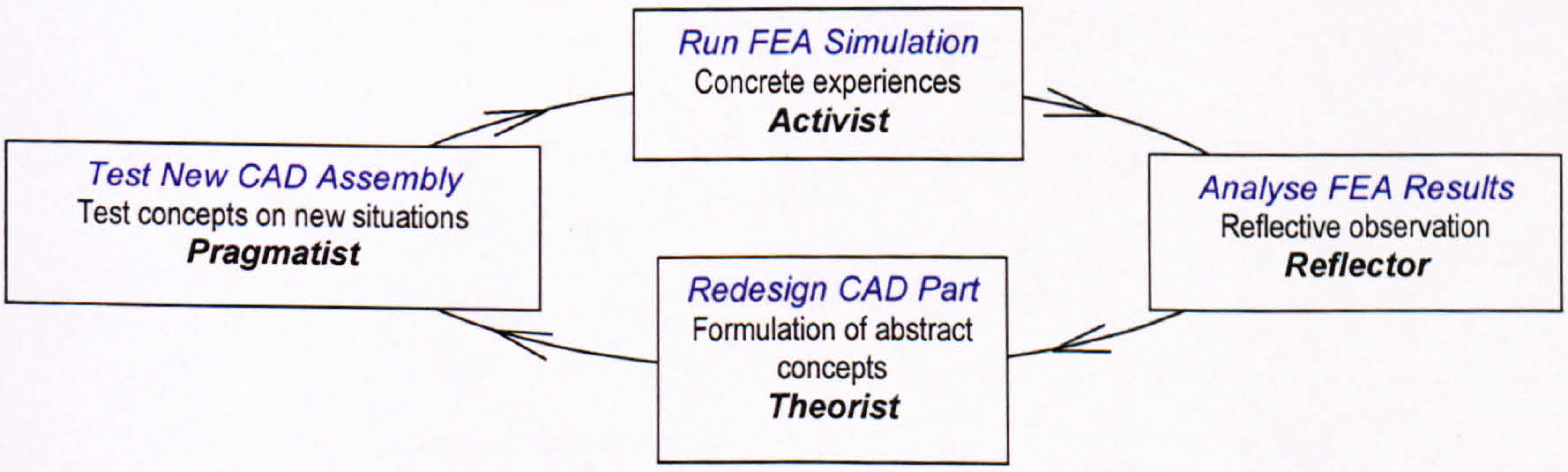
The above can be related to the learning cycle and respective learning styles (Honey & Mumford, 1992; Landen, 1997) using design technology, such CAD and FEA software:

Concrete experiences: Run a simulation, such as FEA on the CAD part to see where the high areas of stresses are, in order to prove that the design is feasible. This is an ***Activist*** learning style where learning is achieved by doing and experiencing.

- **Reflective observation:** Analyse output results, such as FEA. This is a ***Reflector*** learning style where information is gathered before conclusions are reached.
- **Formulation of abstract concepts:** Use the CAD software to model a new part or modify the existing part, based on the FEA results. This is a ***Theorist*** learning style where the reason behind things, concepts and relationships are important for understanding.
- **Test concepts on new situations:** Test the new CAD part in a CAD assembly, to see if part fits. Other design considerations tested include manufacturing and packaging implementations. This is a ***Pragmatist*** learning style by testing the practical application of what is learnt.

Figure 1 illustrates the connection of Kolb's cycle to this typical design technology.

Figure 1: Learning Cycle with Design Technology (adapted from Kolb, 1984)



This continuous learning cycle is typical of work-based design engineering. The author (YJ-G) has experienced this learning cycle at many engineering companies. Each learning style is experienced in order to optimise the design using technology-based techniques. Each stage outputs data for the next, which in context is used as information. The whole cycle increases the individual's (and all those involved) knowledge for the design.

Engineers and managers from many companies were interviewed, and the literature reviewed, to establish how TBL can affect the individual and what it can offer:

- **Computer-based learning** (CBL): This can easily be implemented using existing technology and the IT infrastructure in the company. CBL describes any computer delivering learning via its hard-drive, a CD-ROM, the Intranet or the Internet in order to develop new skills for a specific task or for self-development purposes (Steed, 1999).
- **Web-based learning** (WBL): This is a form of interactive CBL, where the learning material is accessed at a networked computer via an interface called a web-browser, e.g. Netscape or Microsoft Explorer, using the Internet or Intranet as delivery channels (Ravet & Layte, 1997). The Web uses a facility called hypertext or hyperlinks, where text or images are mouse-selected for linking to company or global webpages (Steed, 1999). Here, the individual can collect additional information on the selected topic.
- **Multimedia Techniques:** Individual learning styles can be catered for through using a variety of multimedia techniques, such as text, graphics, pictures, videos, audio, animations, and simulations, together with user-choice. Improved visualisation and interaction with the learning material leads to better understanding and richer learning experiences. The environment is organised to motivate individuals to become actively immersed in their learning process (Landen, 1997), by providing scenes of real-life situations that allow the learner's direct involvement and by using explorative ways through hyperlink selections over the Intranet or Internet.
- **Alternatives:** This recognises the value of testing and adapting resources to meet personal learning needs. Choosing alternative methods of learning, by accessing online tutorials, emailing peers, forum discussions, and searching the Web for relevant literature. Access to relevant information can be from company and global databases, knowledge-bases and libraries. Access to information for the Design Engineers is being developed on many companies Intranet webpages. Present information includes catalogue literature, engineering formulae, material specifications, drawing standards (e.g. BS 308), company design procedures and best-practises, manufacturing processes, preferred suppliers, product information, CAD tutorials, and contact details of project personnel. This knowledge-base saves engineers time obtaining relevant project information, and new engineering graduates use this in their induction programme.
- **Personalised / Customised learning:** Online courses and content can be tailored to suit individual's previous experience and required needs. The Internet provides the means for academic distance-learning courses, e.g. MSc and MBA, and exploratory learning for searching for relevant work-based information, e.g. material composition for the design criteria.
- **Self-directed learning:** The individual can organise time, place, and pace for learning around work schedules. When individuals learn at their own pace, information is more easily remembered (Tarr, 1998). The TBL process offers more flexibility as the information can

come from a variety of sources, and time is efficiently used. Self-paced material can provide a non-threatening personalised and private learning environment with user-friendly graphical interfaces. Self-directed TBL is a convenient way to keep the individual's knowledge current, especially if he or she cannot attend conferences, lectures or meetings due to sickness, holiday or a heavy workload.

- **Assessment:** To measure the individual's performance after a training module, a Web-based assessment can be introduced in order to ascertain if he or she has grasped the new material. The assessment can involve a series of questions in the form of a multiple choice type test, yes or no answers, or picture selections. With this interactive approach, the feedback of the assessment can be instantaneously to the user, stating their performance. Individual choice and judgement about their performance are important. A post-assessment is useful to identify what the individual has understood before progressing to the next training level. A pre-assessment is useful as a refresher evaluation to see how much the individual already knows. This can either be used for self-assessment purposes or for the Training Supervisor to adapt further courses.

- **Groupware:** This technology allows a group of people to collectively work or learn on shared information and documents over the Web: Intranet or Internet (Ravet & Layte, 1997). Groupware allows interactive working and learning with peers, supervisors and collaboration with other departments, sites, suppliers and customers. The tools used can be synchronous or asynchronous tools: Synchronous tools, including whiteboards, video and audio conferencing, allow individuals to interact in real-time over the Web. Asynchronous tools, including email and forums, allow individuals to learn at anytime (French, 1999). Both of which are important for the interactive learning experience to the individual and the group. The basic idea of collaborative learning is that learning is improved by interaction within a group. Individuals also have prior experiences that they can share with the group. One main assumption from this, is that (Petrovic et al, 1998): Knowledge is created as it is shared, and the more it is shared, the more is learnt.

TBL can assist CAD, IT, office software tools and other instructional training that engineers need, by using computerised tutorials, online assessments, online help facilities and by using electronic books, standards catalogues or manuals.

Furthermore, TBL tackles the increasing need for immediate learning and refresher training. As the company encourages all their engineers to engage in self-directed learning, TBL seems an appropriate method. By establishing an effective learning environment, the engineers can use their own initiative and take responsibility for their own training and learning requirements.

Effects of TBL on the Organisation

David Reay (1994) defines learning in an organisation as:

"...a collection of actions which enables the organisation to achieve its goals through enabling, empowering and developing to its fullest, the potential of the individuals within that organisation".

The definition needs to include the provision of an effective learning environment for its employees (Senge, 1992), in order for learning in the organisation to occur. The conditions that need to exist in an organisation for the right learning environment or *Learning Climate* as Mike Pedler et al (1997) and Bob Garratt (1994) describe it as, include the following:

- All employees are encouraged to learn and share what they have learnt to other employees.
- Systems are established in areas of the organisation that requires learning.
- Learning is valued and rewarded in the organisation.
- The organisation continually evolves itself through learning.

The *Learning Climate* promotes self-development in an organisation by aiming to generate, maintain and value learning for its employees. This environment accommodates individual learning through questioning, feedback and support. The learning climate and self-development create learning opportunities in what has been termed as *The Learning Organisation,* or as Mike Pedler et al (1997) describe as *"The Learning Company".* He and his co-authors (1997) describe the learning company as:

"...an organisation, which facilitates the learning of all its members and consciously transforms itself and its context".

The importance about the *learning company* is that it encourages the following:

- Awareness of learning and the development of potential in all the employees who work in the company.
- Development of the company as a whole organisation, including the integration of each employee's learning with that of the company.
- Responsibility of the organisation's members to keep up to date and adapt the learning methods and material as required.
- The learning material must be of some relevance (i.e. be in context) to the company and to the employee's self-development.

From discussions with companies, and from the literature reviewed, the benefits to the organisation of encouraging all employees to become active, self-directed learners are as follows:

- **Efficient learning time:** There is minimal work time lost with just-in-time (JIT) learning and on-demand training. The user can learn anywhere and at anytime at their convenience. This can be described as: Self-paced, self-directed, self-managed, learning-on-demand, JIT training, just enough training, distance learning, and open learning. The individual can immediately apply what he or she learns to the job, when learning takes place in the work environment, e.g. learning Microsoft Project in order to create a required workload and time plan.

- **Cost-effective learning:** WBL provides inexpensive company or global distribution that can be delivered to any networked computer, to a large number of individuals. By using the Internet the organisation need only pay for training required, i.e. *pay-as-you-learn* thus reduced training costs. Programmes can be delivered and re-used with fewer costs than with traditional training methods. There are no expenses required for the individual's travel, subsistence, or accommodation as with off-site instructor led courses.

- **Efficient management:** The self-managed learner is a useful resource to the organisation, given the right training and guidance (Pedler et al, 1997). The empowered individuals can organise their own training and learning methods, thus freeing up their managers to do other tasks.

- **Customisation:** Training courses can be customised to meet the organisation's specific training needs. Flexible CBL and WBL environments can be departmental, product or individual specific.

- **Knowledge exchange and sharing:** Willingness and openness to share new knowledge and skills to others in the team and department (Dixon, 1998). This increases the comprehension of other employees by integration and shared information with other departments, sister sites, suppliers, and customers.

- **Job performance is increased:** Understanding is developed from achieving greater knowledge retention by wanting to learn (Tarr, 1998). Hence, fewer unproductive mistakes are made in the organisation. Self-motivated, self-disciplined, self-reliant, self-assessed, better-trained employees are more autonomous and can contribute better to the whole organisation performance (Pedler et al, 1997).

- **There is a lower turnover of staff:** Employees that are more confident, competent and valued are more likely to stay in the organisation. Organisations that offer ongoing education and training have a higher rate of staff retention and benefit from better skilled employees (Reay, 1994). The engineers interviewed by the author (YJ-G) said that by having the latest technology to use and learn was a deciding factor for them working for the company.

- **Acceptance of organisation change:** Self-directed individuals accept organisation change more readily as they adapt by learning new techniques and processes (Reay, 1994). Howell (1997, cited in French, 1999), a Training Consultant, identifies the self-directed learning benefits to a company by:

  "...employees who see themselves in a learning environment add value to the companies, increase productivity, are more accepting of change, and can adapt to movement within the company".

- **Accessible to current information and new material:** Knowledge and skills within an organisation are continually updated through self-directed learning. Hence, the organisation can adapt quicker to the environment in which it operates, due to better-informed employees (Rosenfeld & Wilson, 1999). According to Steed (1999), skills transfer and retention with self-directed learning, in particularly WBL, is 30% more effective than instructor-led training.

- **Utilisation of existing hardware and resources:** A web-browser provides the interface to the Internet or Intranet and this can access the WBL environment on any platform such as Windows, UNIX, Macintosh, or OS/2. A training programme can be delivered to any networked computer without authoring a different programme for each platform.

- **Consistency and control of training material and revisions:** After the original implementation of a WBL module with links to Web-based information, further programme changes, additions, enhancements, and developments can be made on the server where the programme resides and everyone company-wide and globally can access the latest updated version.

However, there are presently weaknesses of TBL experienced by companies, and reviewed in the literature:

Technical problems:

- Present bandwidth limitations for WBL means performance for sound, video and complex graphics can be slow, causing long waiting times for these files to download over the Internet, affecting the flow of the learning process. This problem is not so significant over the company's Intranet due to greater bandwidths and less traffic. This does not affect standalone CBL, which uses CD-ROMs or the computer's hard-drive to access material.

- Speed of interactive responses can be slow due to the network traffic.

- Internet connection can be lost or broken due to problems with either the internet service provider (ISP), hosting, telephone exchange, or the organisation's IT department.

- The initial development time can be significant for authoring customised webpages for the working or learning environment and integrating the delivery environment, compared to an *off-the-shelf* package. A large proportion of the costs associated with WBL are the start-up costs.

- A technical infrastructure is required within the organisation. WBL development can be out-sourced, but a dedicated team needs to plan for its design and implement, and manage the WBL material. Adequate benchmarking is required to establish the appropriate technologies, including hardware and software requirements for the organisation.

- Present WBL interactivity is often too limited and static. This is being improved, and when it is, the impact on the performance of learning should also improve.

Management problems:

- TBL approach can be too innovative for the non-technical parts of the organisation. TBL needs appropriate understanding and commitment from management and all those involved in the organisation (Gupta et al, 2000).

- Organisations, from the author's (YJ-G) experience, are reluctance to train and learn over the Internet entirely. Distance-learning courses, such as the part-time MSc and MBA courses are more acceptable, where text-based learning is via books with email correspondence to the university supervisors.

- Individuals need to adapt to new methods of working. Decreasing instructor-led training can make learners anxious. Hence, this technology needs to be introduced into the company gradually. All affected individuals need to be involved at the start of any TBL implementation, in order for them to *buy-into* the technology.

- Learning about and implementing new technology takes more time, money, resources, and commitment than generally expected.

- Organisations have a vast amount of knowledge, information and lessons learnt in a wide variety of processes, procedures, company standards, databases, and locked away in individuals' heads (Gupta et al, 2000). This diffused knowledge needs to be managed properly, and be made accessible throughout the organisation by relatively notice users.

- Managers should not feel they have reduced power from the empowered and educated workforce, as they themselves are also employees of the organisation and must also keep their skills current and thus learn. The manager's emerging role in the learning organisation is to act more as facilitator and support the employees through coaching, guiding, mentoring and encouraging continuous learning.

It is the organisation's responsibility and willingness to empower their employees to take more responsibility in their self-directed learning methods and gain the appropriate knowledge.

Most managers, experienced by the author (YJ-G), do encourage learning and view it, not only for a requirement for the job, but also as part of the employee's personal development. Most HR Managers feel that it is important to train *all* their staff – permanent, contract and managerial staff. There are overview courses (e.g. CAD) run in-house for managers. This is beneficial to the organisation as it gives the managers an appreciation of what the technology's capabilities and limitations are.

A problem observed in one company by the author (YJ-G) is that a few managers find it hard to accept learning, especially their own. They accept that the Design Engineers have to have training (e.g. CAD) but are not prepared to go on an overview course themselves. They do not see the benefit to their own job *"as they were not going to use the technology and did not have the time anyway"* quoted one Project Manager. Their HR Manager knows this attitude is an obstacle and is looking into Management & Leadership Training courses. This problem is typical of large bureaucratic companies, such as this, as it is harder and slower to change the learning climate compared to smaller companies (Tobin, 1993, cited in Denton, 1998).

An organisation learns and develops through employees learning and developing (Denton, 1998). Besides the CAD training, Design Engineers in companies regularly attend in-house Time Management, Design Standards, Manufacturing Awareness, and Team Management courses. Weekly German courses are held in-house at many of the companies investigated.

The effective learning climate in an organisation encourages learning in *all* employees. Managers also learn from the process by requesting feedback from employees and question their own assumptions and behaviour (Pedler et al, 1997). Mistakes are viewed as experiments that did not generate the desire results. *Learning by your mistakes* or *by trial and error* is part of the learning process. The non-learning philosophy is to blame someone or something else, or as Mike Pedler et al (1997) put it, *"pass the buck"*. Thankfully the companies investigated are encountering less of the latter in the Design Department.

According to Rosenfeld & Wilson (1999), *"an ongoing career development is possible when initiatives both from the management as well as from the employee him or herself are brought into action"*. The shared responsibility for learning is thus by the organisation and the employee. In the companies investigated, yearly appraisals and monthly meetings are held, where each Design Engineer, on a one-to-one basis with their manager, is encouraged to request his or her own training and further development requirements. The manager also advises the Design Engineer by making recommendations and suggestions for his or her training and development.

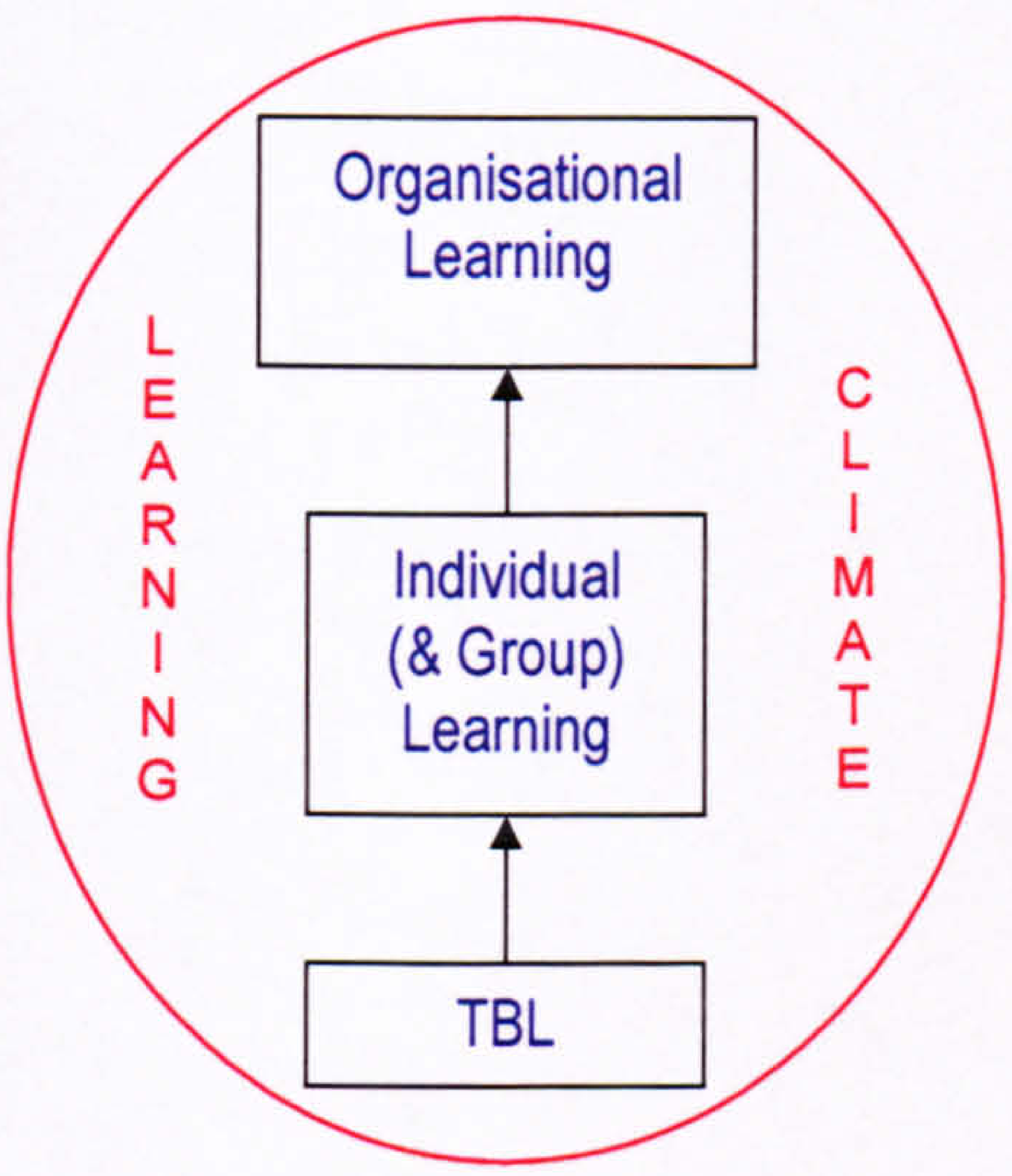
With self-directed technology-based learners, managers still need to co-ordinate and supervise these employees to ensure job requirements are meet. However, employees who are better trained and educated are self-supervising, self-disciplined, self-motivated and more autonomous (Pedler et al, 1997). This is beneficial for any organisation as the managers have more time to concentrate on strategic issues and do other important tasks, including facilitating learning in employees and thus the whole organisation.

Conclusions

Organisations need to facilitate the necessary resources and technology to establish the right learning climate and value individual learning. All employees, including managers, need to be aware of and open to the various TBL methods available.

By introducing the appropriate technology into the organisation's learning climate, the individual can engage in self-directed TBL. The learning organisation co-ordinates the work and learning activities, and encourages all individuals to be involved in learning and sharing information and knowledge. TBL supports individuals, and so develops the organisational learning ability. These issues are summarised in *Figure 2*.

Figure 2: TBL Supporting Individual Learning



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Appendix A3

PAPER 3

The Emerging Self-Directed Learning Methods for Design Engineers

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The Emerging Self-directed Learning Methods for Design Engineers

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Keywords

Learning methods, Self-directed learning, Computer-based learning, Web-based learning, Individual learning, Design Engineers.

Abstract

For learning opportunities to exist in an organisation, adequate learning methods need to be available in the organisation. This paper looks at the various learning methods for engineers in the design environment adopted by two automotive organisations. With greater work demands placed on the engineer and less time to learn in, a more *self-directed* learning approach is emerging.

Emphasis is on the engineering design environment due to the continuous need for Design Engineers to keep updated with current engineering information, knowledge and techniques.

By having the right learning climate and methods available in the organisation, the individual can engage in self-directed learning. The effects of which are beneficial to organisational learning and the Design Engineer's self-development.

Introduction

Various learning methods exist in organisations to cater for the different skills required for the job and the individual learning needs. These methods depend on the learning material, resources, and support available within the organisation. Work-related training and formal instructor-led courses only contribute to a part of the individual's learning, with the increase now to more *self-directed learning* and *self-development* methods. (Pearn et al, 1995). Modern working practices place greater demands upon the individual and as a consequence the individual has less time to learn in (Landen, 1997). Self-development encompasses self-directed and flexible learning approaches, where individuals are encouraged to take responsibility for their own learning and development (Pedler et al, 1997).

The approach taken to investigate the various learning methods was to focus on the design function of two different automotive engineering organisations – *company X and company Y.*

Both companies have an established learning environment. However their management structure and individual responsibilities are different. Company X is an original equipment manufacturer (OEM), medium sized (>50 employees <250) British company with an organic organisational structure. Company Y is a tier-one supplier, large (>250 employees) international company with a mechanistic organisational structure.

The design function was chosen due to the continual need for engineers to keep abreast of current and new design information, knowledge and technologies, such as new design simulation tools, new prototype techniques, new materials and new manufacturing processes. Periodically, design skills or techniques require learning or renewing, such as with computer-aided design (CAD), finite element analysis (FEA), or product data management (PDM). In both *company X* and *company Y*, this engineering design function also has the most individual training carried out and the largest training budget allocation, compared to the other departments in each company.

Interviews, questionnaires and observations, together with the author's (YJ-G) experience of both companies were combined to determine what training and learning methods are being used in these organisations and to what extent self-directed learning is practiced. The people interviewed in both companies included the HR Manager, Design Manager, Training Supervisor, Team Leaders, Project Engineers and Design Engineers.

Instructor-led Training

Presently, the companies investigated rely on two main modes of instructor-led training: lecturing to a group and workshop laboratory sessions. The benefit of instructor led-training includes continual observation of the individuals by the Training Supervisor, in order to assess the level of user understanding, and to respond to user difficulties. Furthermore, this classroom environment provides group discussions and peer evaluations which assists in the individual's learning process. However, the traditional classroom has some inherent limitations which self-directed learning addresses.

Training Supervisors at *company X* and *company Y* provide week-long, in-house instructor-led training courses for specific technical skills, such as CAD, IT and office software. In-house training is the norm for the Design Engineers at both automotive companies. This proves cost effective for the organisations, as it is less expensive to pay an in-house Training Supervisor to teach four or more Design Engineers than to send each Design Engineer off-site to be trained.

Week-long, off-site training proves effective if only one or two employees need to be trained. By interviewing both companies, the author (YJ-G) established that the CAD Supervisor and IT Administrator are trained off-site. Being offsite also gives the CAD and IT Supervisors training experience of the latest hardware and software available, and there are no interruptions from computer issues, user problems, phone calls or meetings.

After the instructor-led training course, the employees are encouraged to adopt a self-directed learning approach and learn on the job, putting their newly acquired skills into context. The Design Engineers are still able to question the Training Supervisor on uncertainties of the material taught and on daily CAD problems. The Training Supervisor now acts more as a coach rather than an instructor.

Self-directed Learning

The self-directed method of learning involves individuals using their own initiative and taking responsibility for their own learning (Pedler et al, 1997), instead of waiting for their organisation to tell them what to learn and how to learn it.

At *company X* and *company Y*, the methods of self-directed learning include work-based learning, referencing books and manuals, asking peer and Training Supervisors for assistance, using online help facilities and computer-based training media to develop their understanding and experience. These methods often follow on from the instructor-led training courses:

Work-Based Learning

Rosenfeld & Wilson (1999) remark that employees learn best in their work environment. The author (YJ-G) agrees with this, as learning in context provides a good learning climate for the employee.

Work-based learning can also be referred to as *learning by doing* or *learning on the job*. Design Engineers tend to work like this, by combining their experience, perception, cognition and behaviour. This can also take into account the differences between learners due to their existing levels of knowledge and experience. Work-based learning, by its very nature, is self-directed and self-paced.

After the CAD training, the Design Engineers *learn on the job*. This is the preferred method of learning in both companies, as engineers become more skilled the more they use the CAD and still produce useful design work. A little more work time is given to the newly trained engineers to allow for their learning.

Design Engineers also increase their engineering knowledge and experiences by using the CAD software to model components. This is because design considerations such as Design-For-Manufacture (DFM), Design-For-Assembly (DFA), material selection, Finite Element Analysis (FEA), dimensional and geometric tolerances, etc., that need to be continually investigated by the Design Engineer.

Book & Manual References

Books, manuals and journals are the simplest form of self-directed learning. This method of learning is private and self-paced.

CAD courses use training manuals. These allow the engineers to work through examples at their own pace, highlight any key points and make their own notes to reinforce their learning. The manuals are also referred back to at a later date if the engineers have problems with specific CAD features.

Design Engineers from both organisations combine book, manual, journal, and catalogue reading with work-based learning for finding engineering formulae, material specifications, drawing standards (e.g. BS 308), company design procedures, researching new engineering processes, reading about the latest plastic fastenings, etc., or just checking design uncertainties. *Company X* has a designated library to house all the above literature in. *Company Y* is considering having a library, in order to stop out-dated reading material and duplicated literature being used in each project team.

Peer & Expert Assistance

Peer assistance is generally required whilst engaging in work-based learning. The individual requests help when reaching a stage where he or she can go no further in their work or learning.

When the individual begins to learn a new skill, e.g. CAD, the Training Supervisor is often regarded as the *expert*, the solver of all technical problems. Design Engineers who are experienced in the certain technologies, such as CAD or FEA, are also classified as *experts*. This type of mentoring system finds individuals initially dependent on the *experts* for help. As the individual becomes more competent, less help is required from the *expert*.

The author (YJ-G) observed (also verified by the Training Supervisor in both companies) that as soon as a Design Engineer had a problem with the CAD technology, he or she would turn to the nearest engineer and ask for help. If they did not know the answer then an *expert* would be asked, or the relevant book or manual was used if an answer could not be found immediately. Finally the CAD Support Centre was called if a solution could not be obtained. These problems became less frequent the more the Design Engineer became experienced with the technology, such as the CAD software.

Weekly project team meetings, held in *Company X*, have the presence of the Team Leader, all Design Engineers, CAD supervisor, and a Manufacturing Engineer. A different Design Engineer chairs the meeting with project milestones, individual workloads, design, development and CAD problems being openly discussed, with peer assistance encouraged to solve the problems. *Company Y* has similar weekly design meetings, except there are two of them. One meeting includes the Project Engineers and the Design Manager, and the other takes place after the former, which involves the Project Engineer and their respective Design Engineers. These different management styles are fundamental of the organic and mechanistic organisational structures within *company X* and *company Y* respectively.

Computer-based Learning

Computer-based learning (CBL) is used to describe any computer-delivered learning to develop new skills for a specific task or for self-development purposes (Steed, 1999). CBL has been easy to implement in both companies as the software uses existing technology and IT infrastructure in the organisations.

Both Design Departments have access to CBL on CD-ROMs to learn office tools software (e.g. Microsoft Word, Excel, Access and Project) and to online help with the CAD software. The latter includes all the book material on the CD-ROM that is available over the Intranet. However, both companies have attempted to install online CAD help via a CD-ROM but this is slow and awkward to use.

Office tools software is learnt when required in the companies. It is apparent from interviewing the Design Engineers that Microsoft Word and Excel are *learnt on the job* without any prior CBL.

Web-based learning (WBL) is an interactive form of CBL, where the learning material is accessed at a networked computer via an interface called a web-browser, e.g. Netscape or Microsoft Explorer, using the Internet and Intranet as delivery channels (Ravet & Layte, 1997). The interactive facility is through hypertext or hyperlinks, where text or images are mouse-selected for linking to company or global websites. Here, the individual collects additional information on a selected topic.

Both companies have an open mind regarding WBL. An interest that both companies are pursuing is online self-assessments, as the methods at present are limiting and not regulated. *Company X* plans to develop Intranet webpages that will contains relevant design information and records CAD learning problems.

Discussion

The Oxford Dictionary (Hornsby, 1974) defines learning as: *"gain knowledge of or a skill in, by study, practice or being taught"*. Acquiring knowledge assumes certain known facts are transferred to the individual, understood and recalled. Hence, the individual generates knowledge from the learning process. This means that the individual discovers things and assigns meaning to information (Petrovic et al, 1998; Davenport & Prusak, 1998).

In the organisation an individual needs to be interested in the material he or she is learning and find the relevance to their current work, or want to learn for his or her own self-development. CAD training courses are good examples of this. From the author's (YJ-G) own experience as a Training Consultant, she has found that many engineers want to learn the CAD software for self-development purposes, as well as making themselves more marketable as Design Engineers for possible future employment.

According to Charles Handy (1993): *"For learning to occur, the individual must want to learn"*. The main obstacle to learning is the individual. This may be due to one or more of the following reasons (Rae, 1995):

- **Perceptual:** he or she may have limited vision to his or her personal needs and what resources are available.
- **Cultural:** he or she, through passed experience, may expect to have traditional training methods.
- **Emotional / motivational:** he or she may have a fear of failure or being ridiculed.
- **Intellectual:** he or she may not believe learning to be a continuous activity.
- **Environmental:** he or she may not be encouraged to take risks.

Self-development and knowledge-based learning issues broaden the individual's experiences and are long term in the organisations. This requires individual commitment on a continuous basis. Hence, individuals need to take responsibility for their own learning to become empowered learners, rather than primarily relying on the organisation. Gibbons discusses that employees need to be proactive and self-directed if they are to maximise the development potential of their learning experiences (Gibbon, 1993, cited in Barclay, 1996).

Many Design Engineers at *company X* and *company Y* request the advanced CAD courses before being asked to attend them, when they feel confident that they have mastered the basic introductory course. By this action the engineers are taking responsibility for their own self-development.

After the job-related CAD training in both companies, the author observed that self-directed, skills-based learning is ongoing. When a problem needs solving, the Design Engineer uses his or her initiative to solve it. This was illustrated when the engineer had a design or CAD software problem, he or she would ask their peers, then refer to books, manuals or use the online help (this was shown by the questionnaires and through interviewing the Design Engineers).

From interviewing the Design Engineers in both companies, the self-directed learning variables that the individuals have some control and responsibility over in the organisation include:

- Pace
- Time
- Environment
- Assessment of learning needs
- Appropriate sequence of learning
- Appropriate experiences
- Resources
- Learning methods
- Evaluation methods
- Learning styles
- Learning outcomes

When individuals learn at their own pace, information is more easily remembered (Tarr, 1998), and the learning process offers more flexibility as the information can come from a variety of sources (e.g. a combination of manuals, peer assistance and work-based) and so time is efficiently used.

However, conditions need to exist in the organisation for having the right learning environment, or *learning climate* as Mike Pedler et al (1997) describe it as, which include the following:

- All employees are encouraged to learn and share what they have learnt to other employees.
- Systems are established in areas of the organisation that requires learning.
- Learning is valued and rewarded in the organisation.
- The organisation continually evolves itself through learning.

The learning climate promotes self-development in an organisation by aiming to generate, maintain and value learning for its employees. This also includes having the right learning attitude, not only of the individual, but also of their managers and peers to encourage and facilitate learning. Lack of encouragement given to the individual by their managers or peers can also be an obstacle to learning. These following related issues were observed in the organisations:

- In *company Y*, a few Design Engineers that did not have first degrees, but wanted to further their education, were supported (financially and morally) by the organisation. However, their immediate boss did not entirely encourage further learning, and as one Project Engineer said, *"he'll be after my job next!"* The Project Engineer interviewed did not value learning, but the organisation did.

- In *company X*, a few Design Engineers are on a part-time MSc Programme and a Team Leader is on a distance-learning MBA. In all cases the individuals had instigated that they wanted to do these second degrees and their managers supported and encouraged them.

The learning climate is developed more at *company X* than *company Y*, as *all* employees are encouraged to learn, share their knowledge with others, and value learning. From observation and interviews, the Design Engineers in *company X* have more control and responsibility over their everyday engineering tasks, self-development and their job-related CAD training. *Company Y's* HR Manager has plans to address these problems.

The main levels of responsibility for self-directed learning, experienced in *company X* and partly experienced in *company Y*, include (Pearn et al, 1995):

- The employee has responsibility for everyday decision making on learning needs, gathering learning information, resource selection and ways of learning.

- The employee's manager and Training Supervisor take responsibility for helping the employee to reach the level of competence he or she wants, acquiring the skills necessary to access learning resources.

- The employee, the employee's manager and Training Supervisor, jointly evaluate the learning outcomes and quality periodically.

By having the right learning climate in the organisation, with the individual having the desire and the ability to learn, and the variety of learning methods available, the skills that the learner can adopt include the following (French, 1999):

- **Openness to new learning methods:** Understand the value of self-directed learning.

- **Analyse learning options**: Identify, evaluate and explore a wide range of resources to learn the same content.

- **Handling rapid change**: Continually identifying and prioritising areas to update skills.

- **Tolerating ambiguity:** Comfortable exploring alternatives and handling uncertainty.

- **Choosing alternatives:** Recognising the value of testing and adapting resources to meet personal learning needs. Choosing preferred method of learning, e.g. by book, ask peer, surfing the Web for downloading information, or CBL.

- **Self-reward**: Recognising the intrinsic value of learning rather than being motivated by extrinsic rewards.

- **Self-disciplined**: Organise learning and work time schedules.

- **Asking peers and experts for help**: Accept that collaborative learning depends on shared assistance, and seek help from experts when required.
- **Help peers learn:** Learn to value teaching others as an effective way to learn and reinforce basic knowledge.
- **Resilience to failure**: Realising that setbacks are part of mastering new skills, especially when updating continually changing technology skills. For example, a minor setback is when the Design Engineer cannot find a particular CAD command after the training course. The engineer selects a few wrong icons until the desired one is found. Hence, the Design Engineer learns by *trial and error* so reinforcing the learning process.

From the latter and discussions with both organisations, the benefits of self-directed learning to the individual can include one or more of the following:

- Self-development, self-awareness, and personal fulfilment.
- Self-motivation due to being in control of the above learning variables.
- Confident to work with others in the organisation and boosts morale.
- Opportunity for pay-incentives, promotion, and reward for achievement (Barclay, 1996).
- Self-worth, self-esteem and feeling of belonging in organisation.
- Learner's ownership of the process ensures learning is personally relevant to the employee's role in the organisation (Tarr, 1998).
- Better equipped to contribute and better qualified to do the work.

From these benefits, the self-directed learning approach for employees, including managers, is the foundation for the development of organisational learning.

Conclusions

By having the right learning climate and learning methods available in the organisation, the individual can engage in self-directed learning. The effects of which are beneficial to the organisation's learning and individual's self-development. These are summarised in *Figure 1*.

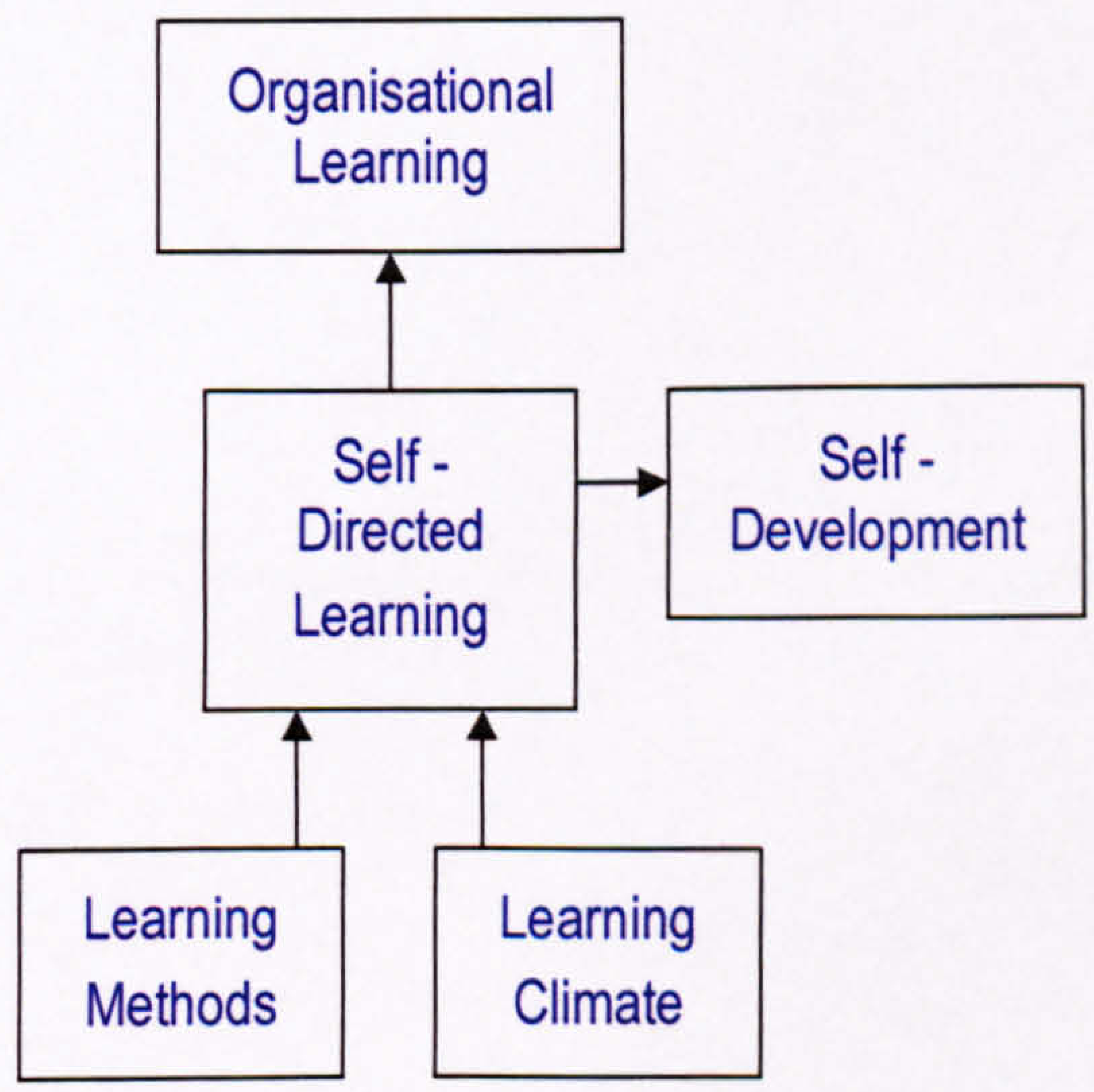

Figure 1: Self-Directed Learning Summarised

Employees and managers need to be aware of and open to the various self-directed learning methods available. Managers, Team Leaders and Training Supervisors will need to act more as facilitators, and support the employees around them through coaching, guiding, mentoring and encourage self-directed learning.

Company X, and *Company Y* to a lesser degree, do encourage their engineers to engage in self-directed learning methods, by allowing them to take their own initiative and responsibility for their own learning and working practices. This is observed after the CAD training courses when the Design Engineers are encouraged to use their newly acquired skills straightway and *learn on the job*. If uncertainties arise, the Design Engineers apply other alternative self-directed learning methods such as referencing books and manuals, asking peers and experts for guidance, using online help facilities, or a combination of these. Online self-assessments and Web-based exploratory facilities are being developed for both company Intranets. The learning climate, especially at *Company X*, also encourages the engineers to share their knowledge, including what they learn, with their peers.

An organisation that facilitates self-directed learning and is aware of the importance of self-development of *all* its employees will develop the organisation as a whole.

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Appendix A4

PAPER 4

External Environmental Forces Affecting E-Learning Providers

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External Environmental Forces Affecting E-Learning Providers

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Keywords

External Environmental Forces, E-learning Providers, Marketing Demand.

Abstract

Before an organisation can develop its marketing strategy, it needs to carry out a thorough marketing analysis in order to understand the customers and trends, and evaluate external environmental forces. This paper seeks to identify and discuss the external environmental forces affecting e-learning providers, including market demand, political & legal forces, social & ethical influences, technology, and competition.

The e-learning provider has little, or no, control over the external environmental forces affecting the market in which it operates, and so it is necessary to continually forecast, monitor and assess this environment and to adapt its e-learning product or services accordingly.

Electronic access

Introduction

E-learning providers are likely to be more successful in attracting customers, if they are more attuned with the marketplace. However, the environment changes the marketplace dynamically over time. Forecasting, understanding and assessing the environment are the greatest challenges and opportunities for e-learning providers. Internet technology provides a new tool to monitor and test this environment. The environment consists of the following uncontrollable factors or variables:

- Market demand
- Political & legal forces
- Social & ethical influences
- Technology
- Competition

These factors need to be measured, monitored and analysed using market research and forecasting techniques. The information collected becomes essential to the decision making of the marketing strategy for a company such as an e-learning provider. The factors are discussed next.

Market Demand

The demand for products and services relies on the economic and behavioural aspects of the consumer. The behavioural aspect such as lifestyle trends creates new market demands and indicates opportunities for new product development. This influences the direction of an e-learning provider's marketing strategy. An example of lifestyle trends includes individuals working longer hours with greater demands imposed on them, giving less time to keep up-to-date with information and to learn in. (Pearn et al, 1995). Also the geographic locations of an organisation increases global business travel for the individuals which creates problems for them keeping informed, trained and educated. The Internet provides the means for e-learning, not only to satisfy the economic and social change, but also the accessibility to the individual for learning, by promoting a self-directed and flexible learning approach.

Demographic changes affect market demand and therefore the market strategy. There is an increase in the number of people that are self-employed and working from home, especially in the service sector (Bickerton et al, 1996). The fastest growing group in higher education is working, part-time students older than 25 years of age (DfEE, 1999). This group tends to seek education to advance their careers, increase their salaries and/or increase their self-development. For universities and business-to-consumer (B2C) training providers, these individuals are ideal candidates for having e-learning delivered to their home or offices.

The market demand for e-learning can include the following benefits to an organisation and the individual:

- **Efficient learning time:** There is minimal work time lost with just-in-time *(JIT) learning* or *on-demand training*. The user can learn anywhere and at anytime at their convenience: *Self-paced, self-directed, self-managed, learning-on-demand, JIT training, just enough training, distance learning, and open learning*. The individual can immediately apply what he or she learns to the job when this takes place in the working environment.

- **Cost-effective learning:** E-learning provides inexpensive company and global distribution that can be delivered to any networked computer, to a large number of individuals. By using the Internet learning the organisation need only pay for *off-the-shelf* training required, i.e. *pay-as-you-learn* thus reducing training costs. Programmes can be delivered and re-used with fewer costs than with traditional training methods. There are no expenses required for the individual's travel, subsistence, or accommodation as with off-site instructor-led courses.

- **Efficient management:** The self-managed learner is a useful resource to the organisation, given the right training and guidance (Pedler et al, 1997). The empowered individuals can organise their own training and learning methods with the e-learning environment thus freeing up their managers to do other tasks.

- **Customisation:** E-learning courses can be customised to meet the organisation's specific training needs. This flexible learning environment can also be department, product or individual specific.

- **Knowledge exchange and sharing:** Individuals can share their new knowledge and skills to others in the team and department. This increases the comprehension of other employees by integrating and sharing information with other departments, sister-sites, suppliers, and customers.

- **Job performance is increased:** Understanding is developed from achieving greater knowledge retention by wanting to learn (Tarr, 1998). Hence, fewer unproductive mistakes are made in the organisation. Self-motivated, self-disciplined, self-reliant, self-assessed, better-trained employees are more autonomous and can contribute better to the whole organisation performance (Pedler et al, 1997).

- **There is a lower turnover of staff:** Employees are more confident, competent and valued, due to the learning climate and are more likely to stay in the organisation (Reay, 1994). Organisations that offer ongoing education and training have a higher rate of employee retention and benefit from a better-skilled workforce. Organisations are becoming aware of the importance of continual training.

- **Acceptance of organisation change:** Self-directed individuals accept organisation change more readily as they adapt by learning new techniques and processes (Reay, 1994). The author French (1999), identifies the self-directed learning benefits to a company by: *"...employees who see themselves in a learning environment add value to the companies, increase productivity, are more accepting of change, and can adapt to movement within the company"*.

- **Accessible to current information and new material:** Knowledge and skills within an organisation can be continually updated through e-learning. The organisation can adapt quicker to the environment in which it operates, due to better-informed employees. According to Steed (1999), skill transfer and retention with e-learning is at least 30% more effective than instructor-led training.

- **Utilisation of existing hardware and resources:** A Web-browser provides the interface to the Internet and this can access the e-learning environment on any operating platform, such as Windows, UNIX, Mac or OS/2. A training programme can be delivered to any networked computer without authoring a different programme for each platform.

- **Consistency and control of training material and revisions:** After the original implementation of an e-learning module that links to Web-based information, further programme changes, additions, enhancements, and developments can be made on the server where the programme resides and everyone company-wide and globally can access the latest updated version.

Political & Legal Forces

The political and legal processes in society affect the way in which an e-learning provider operates. Changes in legal regulations and requirements give rise to many new opportunities and threats, and influence the way in which products and services are marketed. Legal requirements that regulate the marketing and advertising products and services over the Internet include:

- Pricing legislation
- Trade Descriptions Act
- Sale of Goods Act
- Government Standards
- Consumer Rights

There are accredited standards being created for e-learning creation. Both e-learning providers and standards committees are recognising the need to encourage development of Web-based content similar to that of computer software programming. The *Sharable Content Object Reference Model* (SCORM) standards under development by the United States Department of Defence's *Advance Distributed Learning Network* (ADL) address the need for modular, reusable e-learning content in universities and companies to teach procedures and skills. Other accredited standards include development from the *Institute of Electrical and Electronics Engineers' Learning Technology Standards Committee* (IEEE

LTSC); *Instructional Management System* (IMS) *Global Learning Consortium*; *Aviation Industry CBT Committee* (AICC); and *ARIADNE, a European Union project*, that focus on the creation of standards for e-learning content, management and technology. The IEEE LTSC has also initiated the move of this work to the full International Standards Organisation (ISO) standards by establishing ISO Joint Technical Committee 1 (JTC1) Sub Committee 36 (SC36) on Learning Technology. Over twenty different working groups are each creating a separate but related standard within IEEE LTDC. Further information on each of these groups can be obtained at the IEEE LTSC website is http://ltsc.ieee.org.

Social & Ethical Influences

Active involvement by consumer and pressure groups has forced the need for social responsibility and protection of the company's reputation to be important for marketing and operation decisions. In order to maintain a good image and reputation among the customers, e-learning providers must avoid:

- Misleading ambiguous advertising
- Inadequate product and service information
- Hidden financial charges

The following points can present threats to the organisation wanting to implement e-learning:

- E-learning approach can be too innovative for non-technical customers. E-learning needs appropriate understanding and commitment from the customer's management and all those involved in the organisation (Gupta et al, 2000).
- Organisations can be reluctant to train and learn over the Internet entirely. Distance-learning courses, such as for further or higher education, where learning is via books, videos and email correspondences has been more acceptable by organisations.
- Individuals need to understand before accepting any new methods of learning. Decreasing instructor-led training can make learners anxious. Therefore all affected employees need to be involved at the beginning of the e-learning implementation with the e-learning provider. Also e-learning needs to be introduced into an organisation gradually and combined with instructor-led training. This is termed *blended learning* and is more likely to be tolerated by individuals and the organisation.
- Understanding and implementing new WBL technology takes more time, money, resources, and commitment than can be expected.
- Organisations have a vast amount of knowledge, information, and lessons learnt in a wide variety of processes, procedures, company standards, databases, and in individuals' heads. This diffused knowledge needs to be managed and integrated with the e-learning systems properly (Gupta et al, 2000).
- Managers should not feel they have reduced power from their self-directed continually learning workforce, as they themselves are also employees of the organisation and must also keep their skills current and so learn. The manager's emerging role in the learning organisation is to act more as facilitator and support the employees through coaching, guiding, mentoring and encouraging continuous learning
- Ethical concerns, including learner privacy, are a concern to the customer. Internet tools can track

website visitors, and many customers can provide extensive personal information. This many leave customers open to information abuse if the e-learning providers make unauthorised use of the information in marketing their products or exchange electronic lists with other businesses.

Technology

Internet technology has a direct impact for the e-learning providers and for the establishments using their products and services. The Internet is an additional dimension, which supports and is supported by the traditional marketing activities. With e-learning, the Internet provides the technology element that makes up the product and its delivery as well as providing the distribution channels and a means to promote the e-learning product or services by.

Web-based tools and technologies provide the means for designing, developing and delivering e-learning content. The technology includes Web browsers that provide the user interface to the Internet, and HTML (Hypertext Markup Language), the standard language that webpages are written in, that is supported by Web browsers. Web authoring systems assist Web designers to develop the e-learning environments. These consist of either HTML editors or webpage layout programs like Microsoft FrontPage or Macromedia Dreamweaver, and Web development programs like Authorware and ToolBook. Internet tools used can be *synchronous* or *asynchronous* communication tools: Synchronous tools, including whiteboards, video and audio conferencing, allow individuals to interact in real-time over the Web. Asynchronous tools, including email and forums, allow individuals to learn at anytime (French, 1999). *Groupware* is the technology that allows a group of people, or student and tutor, to collectively work on shared information and documents over the Web using the *synchronous* and *asynchronous* tools (Ravet & Layte, 1997).

Customers can use search engines to find any information regarding the e-learning provider and their e-learning products and services offered. The e-learning provider needs to embedded keywords, meta-tags and page titles into their webpages using the Web authoring systems, in order for the search engines to retrieve a description of e-learning provider's website (Hanson, 2000). However, there are problems affecting search engines. A search will sometimes return thousands of *successes*. Facing this, most users will abandon the search if their desired information is not found in the first or second screen. E-learning providers must therefore make sure their important webpages are listed with all major search engines and use their webpage content to place important webpages high on the return list in keyword searches. Portals can provide the customer with concentrated access to information from many sources by combining, hosting and linking e-learning information (Hall, 2000; Ravet & Layte 1997; Steed, 1999).

Currently there are limitations related to the network capacity of the Internet, the *bandwidth*. The bandwidth is the rate at which information moved across the Internet. The reason why video and audio transmission can be relatively slow over the Internet is that the bandwidth cannot cope with the large file sizes (Steed, 1999). Solutions to this are presently being developed by the telecommunications industries. One solution is ADSL (Asymmetric Digital Subscriber Line), which uses the existing copper telephone wires to the local POTS (Plain Old Telephone System) exchange. However, ADSL is commercial new and its availability depends on the local POTS exchange. In the meantime a technology called *streaming* is alleviating the problem for transmitting video, audio and animation sequences, where an application or file is broken down into small chucks and delivers the beginning of the application while concurrently sending the other compressed chunks.

Security is an important area associated with e-learning and a major area of concern with consumers. If corporate training involves sensitive corporate information, or if payment is necessary over the Internet, then a greater amount of security should be used. The following are the main areas related to Internet security (Hall, 2000; Steed, 1999):

- **Access control:** There are techniques to control which users have access to the network. Corporate Intranets are often protected through the use of *firewalls*. This is hardware and/ or software that is a gateway between the internal Intranet and the external Internet. The process of authenticating users by issuing them with username and passwords is another type of access control.

- **Information confidentiality:** Encryption is the technology used to insure information passing through the Internet remains private. It does this by basically scrambling the information from the sender and unscrambling the information for the receiver only. Web-browsers and Web-servers are being developed with encryption technology built in.

The following points can present technology threats to an organisation wanting to implement e-learning:

- Present bandwidth limitations for e-learning means performance for sound, video and complex graphics can be slow, causing long waiting times for these files to download on the Internet, affecting the flow of the learning process. This problem is not so significant over the company's Intranet due to greater bandwidths and less traffic.

- The initial development time and costs can be significant for authoring customised webpages for the learning environment and integrating the delivery environment, compared to an *off the shelf* package

- Internet connection can be lost or broken due to problems with either the Internet service provider (ISP), hosting, POTS exchange, or the organisation's IT department.

- Present e-learning interactivity level can be too limited, and the interactivity response speeds can also be too slow from the network capacity and traffic. These are being improved, and when they are, the impact on the performance of learning should also improve.

- A technical infrastructure, i.e. networked PCs, and resources are required within the customer's organisation. Therefore, the design, development, implementation, security and management of the e-learning content may need to be maintained by an e-learning provider.

Competition

Competition is probably the most dynamic of all the environmental factors affecting the marketplace (Bickerton et al, 1996). A marketing strategy must take into consideration the competitive situation of the environment in which the e-learning provider operates. Successful e-learning providers must satisfy the needs of the customers better than its competitors do in order to win market share. Understanding competitors' strengths and weaknesses, market share and positioning are essential. Careful monitoring and evaluation of the competition, enables the e-learning provider to make better decisions (Kotler et al, 1996).

Not only does the Internet provide access to e-learning for many customers, but also to the competition. It is easy for a competitor to see what other e-learning providers are trying to achieve as well as view their website and e-learning products offered. Currently a strong market growth and relatively low barriers to entry are attracting new e-learning providers, including competitors from other related business areas such as the consulting industry.

Conclusion

The e-learning provider has little, or no, control over the external environmental forces affecting the market in which it operates, and so it is necessary to continually forecast, monitor and assess this environment and to adapt its e-learning product or services accordingly.

A thorough market analysis involves understanding e-learning trends and customers, and evaluating the external environmental forces affecting e-learning providers, including the market demand, political & legal forces, social & ethical influences, technology and competition.

From conducting a thorough market analysis, a clear marketing strategy can be developed that identifies which customers the e-learning provider is to target and where their product or services will be best positioned against the competitors in the marketplace.

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Appendix A5

PAPER 5

Combining Traditional Learning Theories for E-Learning

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Combining Traditional Learning Theories for E-Learning

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Abstract

The current trend for learning environments is to allow the student to have more control of his or her own learning. However, the self-directed discovery-based learning experiences assume that individuals have research and exploratory skills, which they may not have. Therefore, instructional designers need to combine the appropriate parts of both objectivism and constructivism learning theories to facilitate guided and managed discovery learning for an effective learning environment. The individual would have control in discovering knowledge with multiple opportunities to create, organise, and structure information, and contribute to his or her own resources and experiences. The instructor (human or computer) would provide the guidance, support, and feedback to the individual. This paper investigates the non-tangible learning technology of these instructional design approaches for enhancing the e-learning experiences.

Introduction

Technology in education, training or learning is often thought of as tangible computer-based tools, and past work has often focused on these important hard technologies. However, there are non-tangible soft technologies, such as learning theory approaches that enhance the learning experience rather than deliver or manage learning content. The learning theories discussed cover instructional design strategies ranging from programmed instruction of the objectivism approach, to discovery-based learning of the constructivism approach. This paper provides an understanding of the differences between the objectivism and constructivism learning theory approaches and the benefits of integrating their methodologies to provide an effective e-learning environment. *E-learning* represents all forms of electronic learning, including computer-based and Web-based learning.

Non-tangible Learning Technology

Philosophers of technology, such as Bunge, Feibleman, Jarvie, Mesthene, and Skolimowski (cited in Mitcham & Mackey, 1983), tend to view technology as *the organised application of knowledge to solve practical problems*. An example of this is the agricultural practice of the three-field crop rotation. In this process, farmers typically plant a field with corn one year, peas the next, and let the field lie fallow the third year, in order to preserve the soil's nutrients. This concept is a non-tangible technology comprising of ideas and strategies. Some of the most effective soft learning technologies are instructional strategies. Authors such as Merrill and Gagne, (cited in Wild & Quinn, 1998) define instructional strategies as those decisions involved in the design of learning activities, and the presentation and sequencing of the learning content. One of the most important decisions for developing educational material is how the instructional designer can assist learners to process new information and to produce meaningful learning from it, whether or not a teacher or trainer is present. This is normally done by the presentation and sequencing of content. How the learning content will be presented and sequenced is generally determined by what type of learning is required, and how the instructional designer's believes an individual learns. The learning approach adopted by an instructional designer will have an impact on the instructional design strategy selected. At one end of the range is *objectivism*, programmed instruction and at the other end is *constructivism*, discovery learning as illustrated in *Figure 1* (Phillips, 1997; Ravet & Layte, 1997).

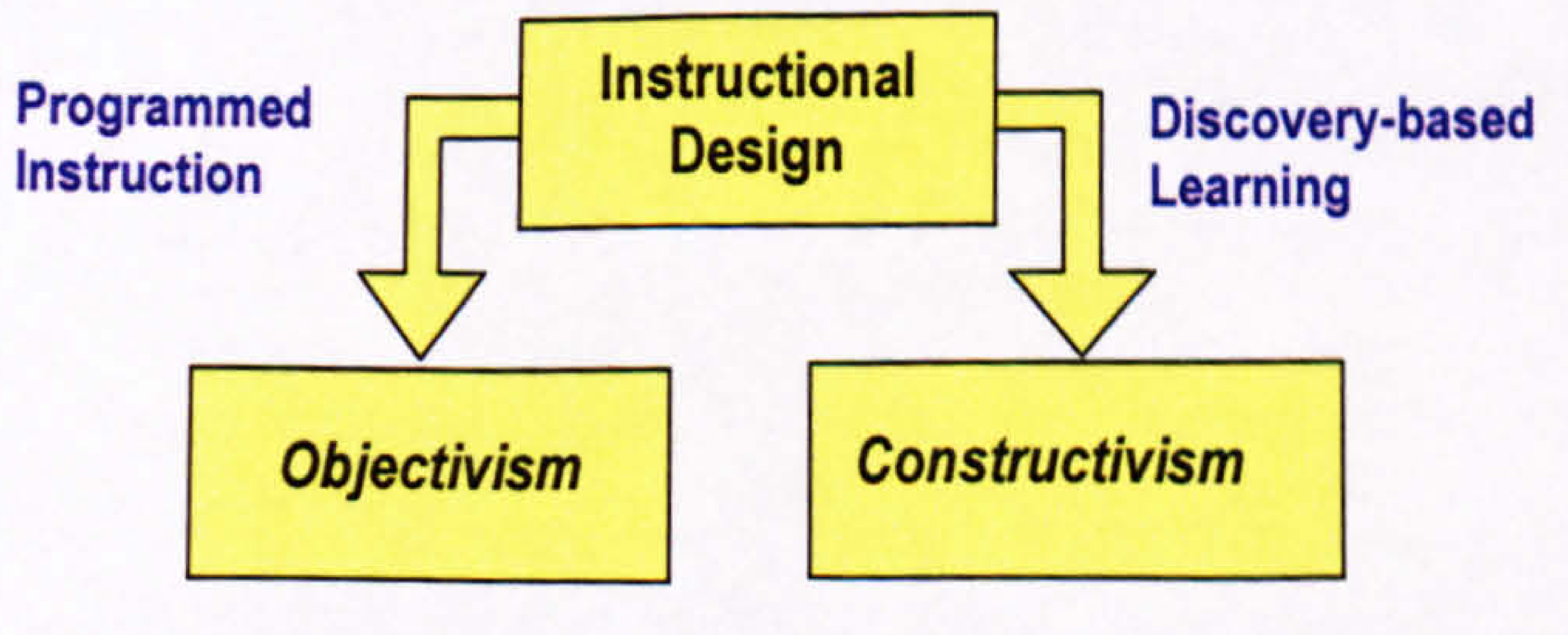

Figure 1: Objectivism & Constructivism Learning Theory Approaches for Instructional Design

Behavioural Psychology

Historically, teachers and trainers have used objectivist methods where students are presented with information, which they repeat back to the teacher or trainer. The underlying model of objectivism is *behavioural psychology*. This psychology uses resulting behaviours, which can be modified by consequences based on rewards and punishments. The following list summaries the main learning approaches of objectivism:

- The teacher or trainer controls the learning process.
- Standard presentation of content
- Question is put to student.
- Student is told if answer is right.
- Positive reinforcement for right answers.
- Negative reinforcement for wrong answers, and cycle is repeated
- External knowledge exists for learners to memorise.
- Progress from general to specific content.
- The student learns meaning.

Hence, the respective behavioural psychology can be summarised as the following (Skinner, 1938, 1974, cited in Phillips, 1997):

- The psychology is based on observable behaviour.
- The behaviour is determined by outcomes or consequences.
- Knowledge is manifested in behaviour, such as achieving correct answers.

Objectivism in E-learning

The first e-learning systems, notably computer-based training (CBT), were designed to be stand-alone and self-functioning, with little or no human expert intervention. One of the pioneers in computer-based education was Dr. B.F. Skinner from Harvard University. His behaviourist philosophy helped form the development and design of these first learning machines. CBT was seen as a way to standardise traditionally delivered instructor-based training. This *objectivist* training approach used the computer as the *"instructor in a box"*, to deliver lecture-based instruction. The stages of the CBT focused on *drill and practice* to master the content presented, and the learner absorbed the content delivered by the CBT. This supported objective assessment and assignments, and used instructor prepared material and a sequenced course. Since this approach is how most education is delivered, the objectivist approach is to put the teaching process online by using multimedia capabilities to imitate books and videos. This traditional method of delivering instruction is in most e-learning environments currently, including Web-based learning and distance learning programmes (Khan, 1997; Ravet & Layte, 1997; French, 1999).

CBT often focuses on tasks that produce easily quantifiable errors, like exams, which can be analysed by the computer system and corrected quickly. Content is seen as a stimulus that produces desirable behavioural changes, i.e. learning in the student. It is thought that given enough iterations, students will eventually make no more errors, and so *know* the information contained within the CBT.

Cognitive Psychology

Constructivism, which is based in *cognitive psychology,* is an alternative approach of how individuals learn, absorb knowledge, and are viewed as active processors of information. People are knowledge-searchers who transform and interpret experiences using developed biological and mental structures. They absorb new knowledge by producing cognitive structures that are similar to the experiences they engaged. They then adapt themselves to these newly developed knowledge structures and use them within their collection of experiences as they continue to interact with the environment (Piaget, cited in Ryan et al, 2000; Wild & Quinn, 1998).

Constructivists believe that knowledge is not separate from, but embedded within experiences and interpreted by the learner. Hence, knowledge is about interpretation and making sense of the environment, and each person conceives it in different ways based on their prior experiences, belief structures, and perspective. From the constructivism view, interpretation can include different types of knowledge construction and not memorisation of factual knowledge or procedures. The aim for the learner is to build and re-invent knowledge; order and re-order knowledge, test it out, and justify this interpretation. These are the underlying principles of constructivist practices (Eysenck & Keane, 2000; Wild & Quinn, 1998). Kolb (1984) provides a useful model of processes involved in constructivist learning. Kolb proposes that learning is a cyclic activity with four stages: concrete experience, reflective, abstract conceptualisation, and experimentation. The following list summaries the main learning approaches of constructivism:

- The student controls the learning process.
- The student constructs knowledge, based on his or her own perspective and experience.
- The learning process is different for each student.
- Encouragement of discovery learning and self-directed exploration.
- Construction of concepts, schema, and mental models.
- The teacher or trainer observes, coaches, facilitates and guides.
- Progress from specific to general content.
- The student creates meaning.

Hence, the respective cognitive psychology can be summarised as the following (Phillips, 1997):

- The learner is an active processor of information.
- Emphasis is on internal mental situations.
- Consideration is given to perspective, learning styles, experience and knowledge of learner.

A important aspect of constructivism is providing a rich self-directed interactive learning environment. Constructivists feel students should be able to independently explore information to obtain content, concepts, relevance, and learn how to learn. According to Ryan and his co-authors (2000):

"The learner is not a passive recipient of knowledge but an active participant in the process of learning"

The author agrees with this important statement made by Ryan and his co-authors. With this shift from giving information to the passive student sitting on the other side of the screen, to engaging the student in becoming a part of the learning environment, the entire concept of online learning has changed. Constructivist learning environments should provide multiple ways for students to explore, together with multimedia that combines text, graphics, sound, pictures and videos to enhance their interactive learning experiences.

Constructivism in E-learning

E-learning providers are beginning to use the qualities of constructivism as well as objectivism. By integrating Web-based tools and techniques into the training process, a *constructivist* approach to learning emerges. Constructivist models have the instructor, tutor or trainer as facilitator and coach, and focuses on constructing assessment and assignments during the learning process. This begins with a learner-centred design and directs discussion through questions and group communication, evolving and reinforcing the learning experience. The instructor's role is to provide guidance, suggest resources, provide questions, and use outside experts for particular learning tasks. Assessment is focused on the process of collaboration and producing of suitable materials. The introduction of the Web as an enabling technology for learning has allowed the constructivism approach to be more acceptable to academics and corporate trainers.

Integration of Constructivism & Objectivism

It is not the aim in this paper to provide a complete understanding of objectivism and constructivism learning theory approaches. The author views these not as competing instructional methodologies, but rather an evolving progression in the development of e-learning environments. In general, objectivist methods emphasise presentation of the learning content and replication by the students. Students are characterised as information-receivers, and tutors as the information-givers. Alternatively, constructivism emphasises the interpretation and creation of knowledge. Students are self-directed, and the role of teachers or computer programs is to support the students' process of individual discovery of knowledge.

It is the author's belief that e-learning systems in the future will succeed only if they enable the learner to learn more effectively and efficiently. The constructivist approach is to ensure that the learning environment is as rich and interactive as possible. However, discovery-based learning assumes that individuals have research and exploratory skills, which they may not have. Therefore, instructional designers or training developers need to combine other technologies, such as human factors, user interfaces, multimedia, systems and telecommunications, to design and deliver the most appropriate learning solutions. Guided and managed discovery learning can be an effective learning environment, which incorporates the appropriate parts of both objectivism and constructivism learning theories. This balance will be different for each learning application. The individual would have control in discovering knowledge with multiple opportunities to create, organise, and structure information, and contribute to his or her own resources and experiences. The tutor (human or computer) would provide the guidance, support and feedback to the individual, with well-defined learning objectives in terms of expected user performance, assessment to measure user performance and understanding, and relevant practice for the required knowledge or skills from tutorials and *drill and practice* exercises. The development, delivery and management of learning content with the associated learning activities can incorporate the guided-discovery learning approach in activities such as self-assessments, self-directed synchronous and asynchronous communications, online help facilities, and interactive e-learning tutorials.

Conclusion

The learning theories of constructivism and objectivism approaches are important soft technologies that need to be considered when developing a learning environment. An effective solution would be to have a learning environment that guides and manages discovery learning, by incorporating the appropriate parts of both constructivism and objectivism learning theories. The individual would have control in discovering knowledge and the tutor (human or computer) would provide the guidance with support and feedback.

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Appendix A6

PAPER 6

Designing E-Learning Environments for Engineers

James-Gordon Y E; Bal J; (2003)
ED-MEDIA 2003 World Conference
of Educational Multimedia, Hypermedia, & Telecommunications;
Published by Association for the Advancement of Computing in Education, Hawaii, USA.

This poster paper accompanied the poster presentation and had to be limited to two pages.

Designing E-Learning Environments for Engineers

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Abstract

The purpose of this poster presentation is to illustrate the various integrated factors that impact on the design of e-learning environments for engineers. Central to this, are the different learning principles, theories, and domains that need to be considered when designing e-learning content. General e-learning design issues are summarised, with specific topics highlighted for the engineering environment. In developing e-learning environments, the focus can be directed too much on the technology with the actual content being considered and added afterwards. E-learning providers need to be aware of the fundamental issues that should be considered to produce and maintain an effective e-learning environment. As the factors cannot be compared directly, a framework is developed that groups associated issues together as philosophy, content, delivery, management, or technology categories, in order to provide guidance for designing successful e-learning environments.

Introduction

Technology providers often overstate the importance of technology in the development of e-learning environments, and emphasis that a complete *Learning Management System* (LMS) can provide all that is required to implement e-learning. Often in developing e-learning environments, the process ends up as a technical one, resulting in expensive implementations, essentially untouched by the uninformed potential users. The e-learning providers, especially the instructional designers or training developers, should be aware that the technology needs to align to the content and not the other way round, but at the same time they do need to appreciate the technological capabilities. Therefore, the providers need to recognise the basic components that contribute to produce an efficient and effective e-learning environment. A way to achieve this is to develop a framework that consolidates and integrates the various factors that affects the e-learning environment. This framework includes instructional principles, methodologies, theories, approaches, techniques, processes, models and guidelines that relate to the design of the e-learning content. This should guide and facilitate the decisions of e-learning providers with regard to choice and design of each e-learning component for an engineering department or organisation programme.

Categorising E-learning Factors

The purpose of this poster presentation is to outline the various factors that impact on designing e-learning environments for engineers from the author's research. The factors cannot be compared directly with each other, but as they are expressed in a framework, associated issues can be grouped together in categories, and include:

a) **Philosophy:** In this context, philosophy includes the learning principles, objectives, styles and domains for e-learning.

- The *learning theories*, a sub-set of learning principles, underlie the methodologies and approaches for the design of e-learning content. These range from the programmed instruction of the objectivism approach, to the discovery learning of the constructivism approach.
- The *learning objectives*, which describe how the instruction is to be designed and how the learning outcomes need to be assessed, as well as assist the learners organise their learning efforts to meet the objectives.
- The *learning domains*, which represent the different motivational, knowledge, understanding, or communication levels of the learners. The representation of e-learning content is important for matching against the different learning styles.

b) **Content:** The structure of e-learning components includes a model of learning activities to be performed; reusable manageable learning objects; a process map of the activities for the model; the knowledge within the activities; and the resources and guidance available. Navigation paths in and between activities need to maintain consistency in their design and use, in order not to confuse the learners.

c) **Delivery:** This essentially is the user interface with its usability issues affecting the e-learning design. This can include navigation structure, readability, and multimedia application.

d) **Management:** This includes instructor and learner tools for tracking, assessing, grading, document managing, and administration facilities. Tracking learner performance can be based on participation and performance in activities, simulations or complete lessons, as well as collaborative work with peers and sharing information, and not just multiple-choice or true/false testing. Managing an e-learning programme takes account the evaluation issues of training effectiveness, measuring learner achievement, and cost effectiveness.

e) **Technology:** The enabling tools and techniques provide the infrastructure for the e-learning content, from its philosophy and management components to the delivery environment of the content.

The *technology* needs to fit *content*, especially with the delivery and management techniques needing to be designed with the content in mind and to suit the learning objectives. However, consideration does need to be given to the capability of the technology when designing and developing the content. The e-learning delivery environment contains and manages the user interface and it delivers the content to the e-learning environment. Depending on the specific learning requirements and associated learning philosophy and management, the relative mix of content can vary. The role of the learning delivery environment is to integrate the learning content together in a transparent way, enabling the learner to navigate effortlessly between activities. These can include accessing, using and interpreting the content, collaborating on activities involving the content, and assessing or testing the knowledge or skills acquired from the content. A feature of the e-learning environment is that the content can be customised to the learner's specific requirements by taking into account the learner's prior knowledge, skills, and experiences.

Designing E-learning Content for Engineers

Designing effective e-learning content is also important for ensuring participation of the learners. Building instructional principles into the design of e-learning helps facilitate learner satisfaction, motivation and confidence with the e-learning activities. Here, the emphasis for designing e-learning content is for the engineering environment, and so this research predominantly focuses on engineers' learning. There are areas in e-learning that are limited in providing effective e-learning solutions for engineers. The author's previous research has assisted in addressing the following under represented learning preference:

a) **Learning content presentation:** Engineers have a significant visual learning style, and so best learn by what they see. Therefore, the presentation and usability of the e-learning content, and the user interface are important for this professional group.

b) **Experiential learning:** This is often referred to as *learning by doing*. Engineers tend to work and learn experientially, by combining their experience, perception, cognition and behaviour, and so learning activities need to reflect this. Experiential learning also takes into account the differences between learners due to their existing levels of knowledge and prior experiences.

c) **Self-directed discovery-based learning:** Generally, engineers take responsibility for their own learning process and are self-directed learners. The discovery-based learning approach is important for engineers due to the nature of their work in using exploratory skills to establish optimum solutions to problems. Collaboration features as well as the problem solving features are necessary for engineers and should be included in learning activities. A learning environment evolves differently for each engineering learner based on his or her individual discovery-based learning experiences and shared information from peer collaboration. Tracking and recording learning experiences is not only beneficial for the tutors and instructional designers but also for the self-directed engineer to monitor his or her own progress and performance.

Conclusion

In summary, this research illustrates the important factors that influence and contribute to the design of effective e-learning content for the engineering environment. These factors comprise of various principles, methodologies, techniques, approaches, and guidelines that cannot be compared directly with each other. Therefore, a framework has been developed that groups associated factors together under philosophy, content, delivery, management, or technology categories. The framework helps to organise and structure these issues in the categories, with the technology selected fitting to these issues. The purpose of the framework is not only as an academic tool but it provides practical assistance for guiding e-learning design, evaluating an e-learning programme including its effectiveness, and assisting in the selection of its enabling tools and techniques. However, the framework is not supposed to be complete, but it will evolve through its application to produce a more effective framework for designing e-learning content for engineers in subsequent e-learning projects.

APPENDIX B

E-LEARNING FRAMEWORK APPLICATION

Appendix B presents an overview of the e-learning framework's application. This is achieved by identifying the path through the framework which is made up of stages for developing specific e-learning activities. The framework is applied to two example academic lessons and the activities within them. The lessons are taken from the Information & Communications Technologies (ICT) Module which forms part of the Electronic Engineering Business Management (E2BM) MSc Programme. However, these have been adapted to illustrate a complete e-learning environment or a blended approach, for an introductory lesson and a syndicate group lesson on the topic of 'networks'. Section 3.4 identified the generic path through the framework, and appendix B illustrates this with the examples to identify how the framework can operate to provide assistance for e-learning providers.

The framework guides e-learning providers through its categories to select, link and order relevant learning factors to develop e-learning activities for improving the basic learning content. Not all factors need to be considered, but they can be added later as the e-learning activities evolve. The intention of appendix B is not to go into the detail of the development of the e-learning activities in the examples, but to identify the selection, integration and sequence of the learning factors. From this, the e-learning providers can identify what factors need to be examined further to proceed with the e-learning development. Specific details on the learning factors and further examples of their application can be obtained from chapter 4.0.

The complete e-learning framework is illustrated in figure B-1, and its guide is presented in figure B-2. These figures can be referred to in the stages through the framework's categories with the two examples, which are described next.

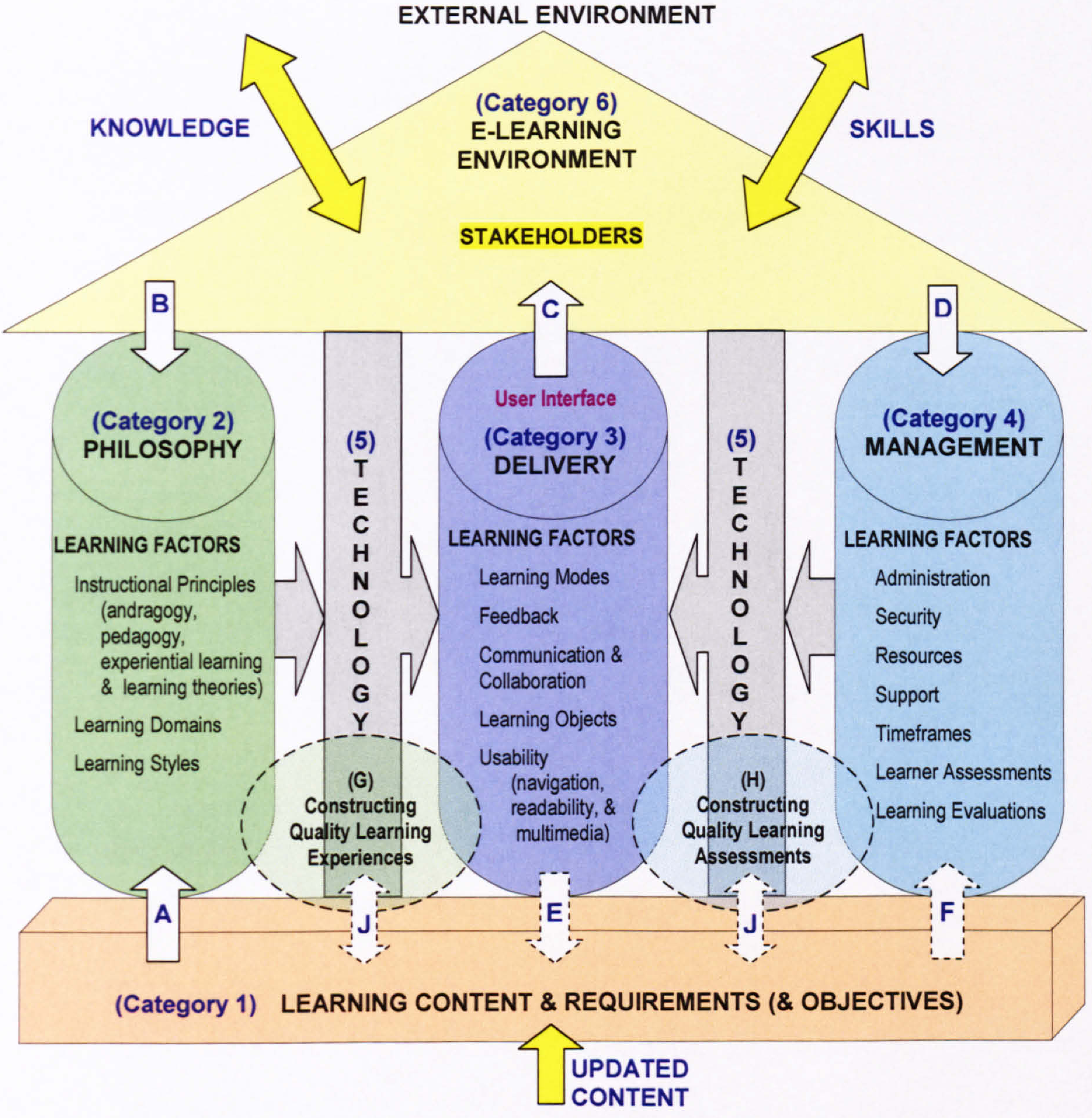


Figure B-1: Framework for the Design & Development of E-learning Content

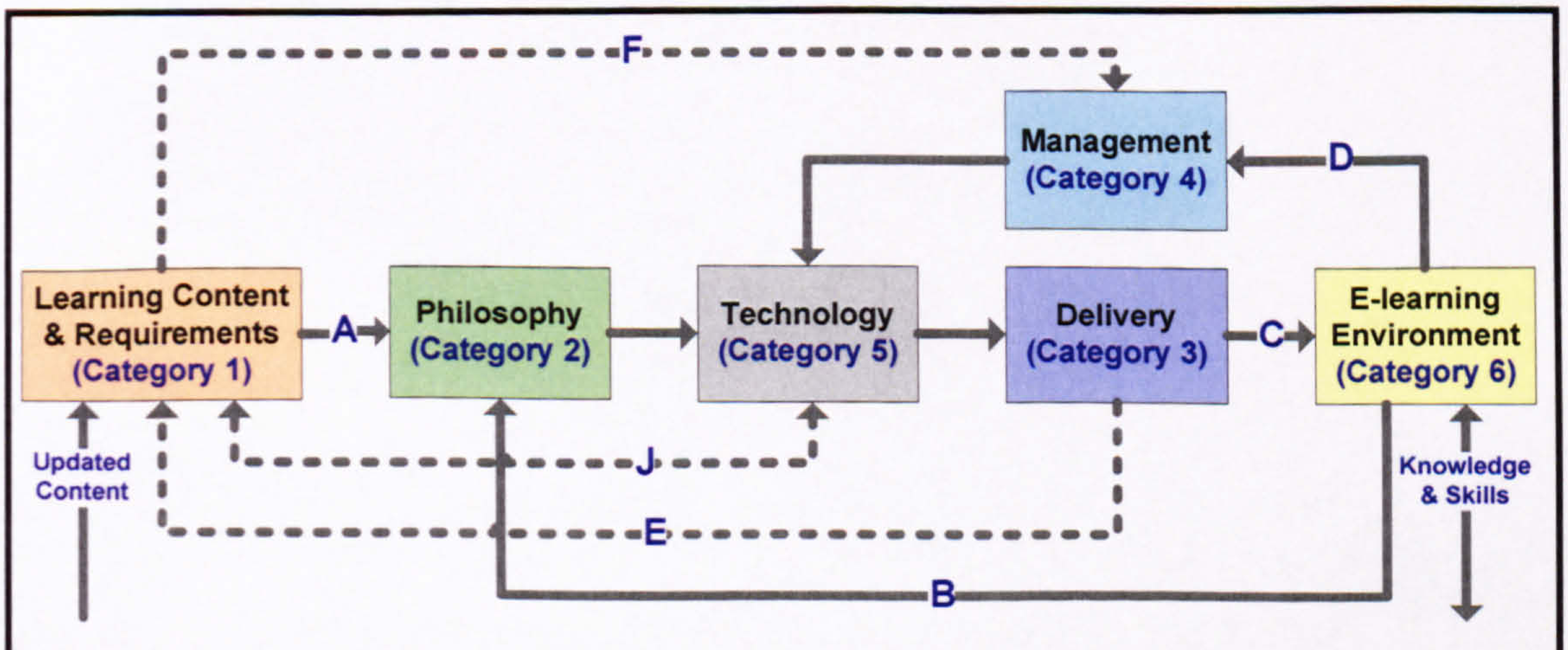
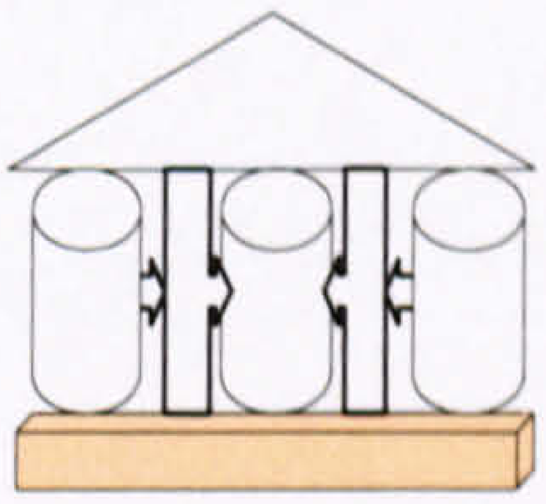


Figure B-2: Framework Guide: Complete Path Flow through Framework

Stage 1 – Learning Content & Requirements



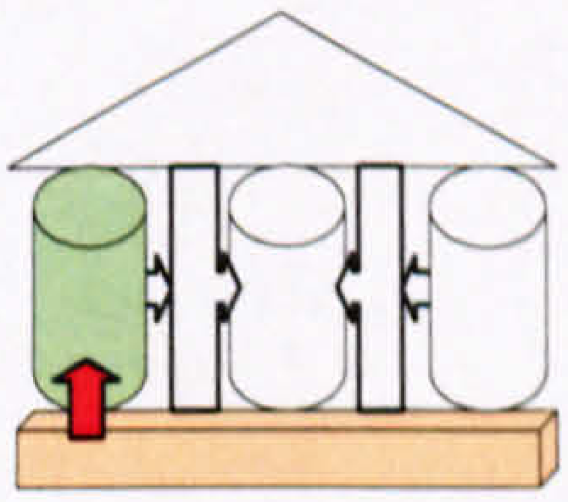
Lesson A - Introduction to Networks

- **Learning Content:** Structured fundamental network information that is content-centric. Examples are given of how networks operate.
- **Learning Requirement:** To familiarise students with network terminologies, types, interaction and selection. Outcome to be a self-assessment and students can revisit weak areas. (Self assessment to be added after pilot running.)

Lesson B - Network Design Case Study

- **Learning Content:** Structured case study information that will become learner-centric as existing knowledge brought into lesson will shape the group activity.
- **Learning Requirement:** To collaborate on the design & testing of a complex network and the final outcome is to present work to the other syndicate groups.

Stage 2 – Philosophy Aspects



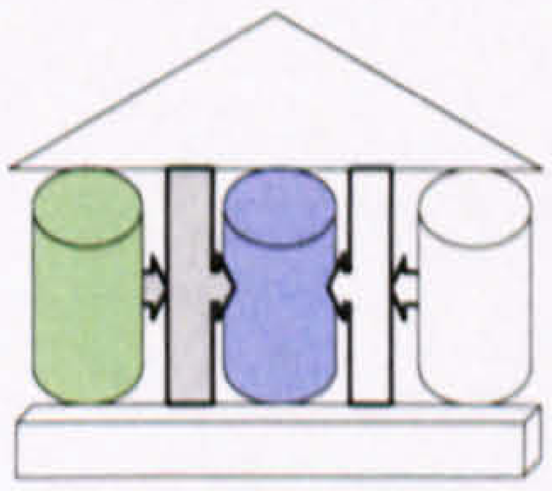
Lesson A - Introduction to Networks

- **Instructional Principles = Pedagogy Approach & Objectivism Theory:** The Module Tutors decide what the students learn and the same content is presented to all students. Learning is by acquisition.
- **Learning Domains = Attention:** The motivational level of the learning domain is at the first stage of achieving and maintaining the student's 'attention' and interest.
- **Learning Styles = Theorist & Visual:** The reason behind network concepts and relationships are learnt. A visual representation of the Module Tutor with a streamed commentary can be considered for introducing the topic of networks and stating the objectives of the lesson.

Lesson B - Network Design Case Study

- **Instructional Principles = Andragogy Approach, Constructivism Theory & Experiential Learning:** The case study is task-oriented and experiences gained from previous lessons are brought into the syndicate group work. Students take responsibility for how they progress and share their knowledge with the group. Learning is achieved by iteratively creating and testing a network design. Learning is by participation.
- **Learning Domains = Relevance, Confidence:** The 'relevance' of the network content learnt is related to the case study. The 'confidence' grows as students demonstrate their newly acquired knowledge and have feedback from their peers in the syndicate work.
- **Learning Styles = Pragmatist & Visual**: Students pragmatically test what they have learnt before in the case study. (The 'activist' and 'reflector' learning styles are more likely to be adopted in the post-module work.) Graphical representations can be incorporated in the network design using diagrams and icons.

Stage 3 – Initial Technology Selection:



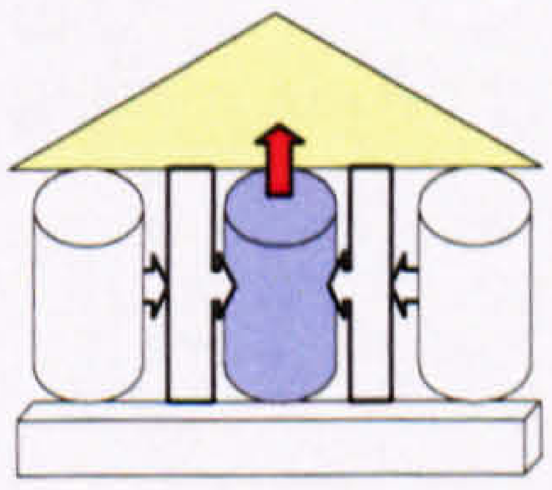
Lesson A - Introduction to Networks

- **For publishing initial learning content online**: Investigate and select the appropriate authoring tools or dedicated Content Management System. A Web publishing tool developed by E-Lab and used at WMG is 'SiteBuilder', which can author, edit and manage the learning content. SiteBuilder also has the facility to encompass Web languages such as Java, JavaScript and raw HTML.
- **For viewing & accessing content online:** Web-browser, hyperlinks and search engines to be utilised.

- **For providing visual, interactive & animated activities:** Examine other Web formats such as Plugins, video streaming and media files. 'Macromedia' Web development products can be considered for this and then incorporated within SiteBuilder.

Lesson B - Network Design Case Study

- **For publishing case study online**: Again investigate and select the appropriate authoring tools or dedicated Content Management System such as SiteBuilder.
- **For viewing and accessing case study discovery learning activities:** Web-browser, hyperlinks, search engines and virtual libraries to be utilised.
- **For providing group communication:** Asynchronous communications for group discussion forums & email. Consider synchronous communication for groups such as dedicated and timed chat-rooms.
- **For group Web-based interactive working:** Develop a VLE for the group to visually build their case study network and estimate the cost. Drag & drop icons for the network equipment and text/ numerical inputs for working out real-time costing for the case study can be created for this.



Stage 4 – Initial E-learning Delivery:

Lesson A - Introduction to Networks

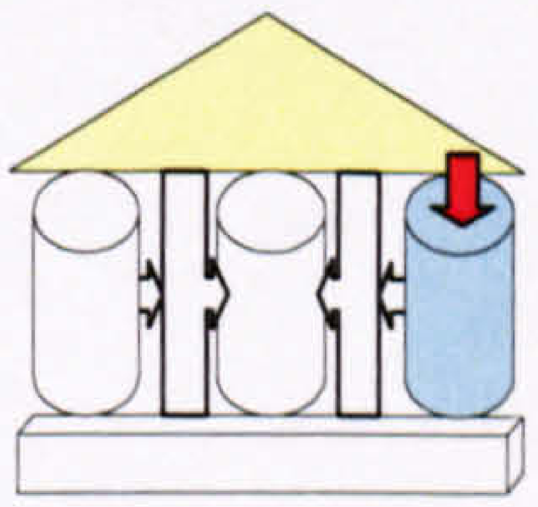
- **Learning Modes = Presentation and demonstration**: Streamed video of instructor-led classes for the e-learning environment or face-to-face instruction for the blended approach. Online animations, demonstrations and power-point presentations for conveying the basic network functionality.
- **Usability Issues:** Templates can be considered to provide a uniform look & feel to the user interface. Readability and layout of the interface needs to be appropriately considered with the stakeholders.

- **Learning Objects:** Modular lessons to be reused in other lessons. The introduction on networks can be utilised in a programme's overview lesson.

<u>**Lesson B - Network Design Case Study**</u>

- **Learning Modes = Guided & Self-directed**: Syndicate group work on case study activity involves assistance from peers in the group, as well as prior experiences brought into the group.

Stage 5 – Management Factors:



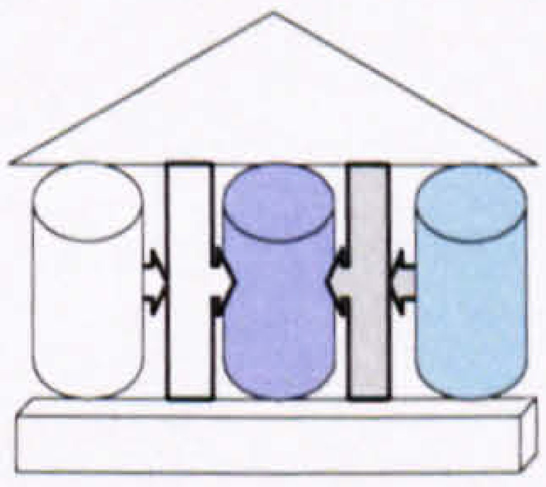
<u>**Lesson A - Introduction to Networks**</u>

- **Learner Assessment**: An online self-assessment can be added after testing the initial running of the introduction lesson, once the learning content is evaluated.
- **Administration:** Record each learner's progress using SiteBuilder.
- **Security:** Unique access privilege for each student doing the self-assessment. **Support:** Provide online support from Module Tutor.
- **E-learning Evaluation:** Measure the individual's knowledge of networks from the self-assessment. This is level 2 of Kirkpatrick's evaluation model.

<u>**Lesson B - Network Design Case Study**</u>

- **Administration:** Monitoring syndicate group work activity. SiteBuilder enables learners to be tracked and provides statistics on their activities.
- **Security:** Access privilege for only group members and Module Tutor. SiteBuilder allows permissions to be edited and users to be added.
- **Support:** Provide online support from peers and Module Tutor.
- **Peer Assessment**: An online peer-assessment can be added to comment on presented work from other syndicate groups.

- **E-learning Evaluation:** Measure how each group felt about the case study activity using online 'smile sheets'. This is level 1 of Kirkpatrick's evaluation model.



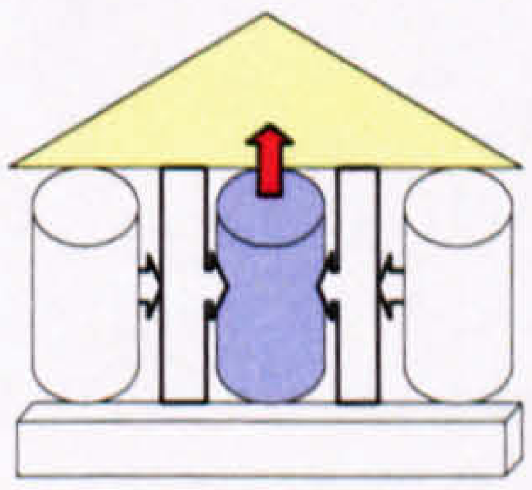
Stage 6 – Further Technology Selection:

Lesson A - Introduction to Networks

- **For Self Assessment:** An assessment management system can be incorporated into the e-learning development. WMG uses 'Questionmark Perception'. This enables e-learning providers to author, schedule, deliver and report on developed tests. Tests also can be developed using Microsoft Excel.
- **For viewing & accessing further content online:** Consider hyperlinks and virtual libraries for accessing further background reading on networks in weak areas.

Lesson B - Network Design Syndicate Group Case Study

- **For recording group work:** Group 'Weblogs' or 'blogs' can be used to post results and record the group's interactions and discussions with each other. A virtual library can be created to allow the group to add hyperlinks to share useful links with peers.



Stage 7 – Further E-learning Delivery:

Lesson A - Introduction to Network

- **Learning Modes = Self-directed:** This is a consequence of the self-assessment added.

Lesson B - Network Design Case Study

- **Feedback:** Comments by peers and instructor after group presentation.
- **Collaboration:** This can be achieved online by discussion group forums, or group and individual blogs.

Table B-1 presents a matrix identifying learning factors that can be considered for developing different engineering e-learning environments that were case studied in the research. The WMG Standard Educational Lesson incorporates the two examples in this appendix, and is highlighted in the matrix. The section numbers are shown on the matrix's left-hand side for further reading.

The matrix presents a selection of the framework's learning factors that can be mapped against learning activities which contribute to the content's development. Not all factors need to be initially considered but can be added or changed as the e-learning content evolves. The different weightings in the matrix represent the different level or type of features within the framework's factors. This helps define the characteristics of the underlying e-learning approach and to determine the appropriate technology infrastructure for a particular combination of factors within the framework. Thus, the matrix illustrates different features within the factors and different combinations of factors within the framework, which contributes to the development of different engineering e-learning applications.

Table B-1: Matrix of Different Engineering E-learning Applications against Framework Learning Factors

SECTION	FRAMEWORK LEARNING FACTORS	KEY	E-LEARNING APPLICATIONS CASE STUDIES						
			COMPANY X			WMG		CISCO SYSTEMS	
3.3	Learning Requirement		Immediate Task Specific			Structured Knowledge		Immediate & Structured	
3.3	Learning Activity		Self-directed Engineering Information	Customised CAD Training	Standard CAD Training	Standard Educational Lesson	Post Module Assignment	Customised Work-based Task	Self-development
4.1	**Instructional Principles:** Learning Theory	i	Cs	O, Cs	O	O, Cs	Cs	Cs	Cs
4.1	**Learning Domain:** Affective	ii	1, 2	1 to 4	1 to 3	1 to 3	2 to 4	1 to 4	2 to 4
4.1	**Learning Style**	iii	T,Pg,V	T,Pg,A,R,V		T,Pg,V	T,A,R	T,Pg,A,R,V	
4.2	**Learning Mode**	iv	4, 5	3 to 5	1 to 5	1 to 4	4, 5	3 to 5	1 to 5
4.2	**Feedback /Collaboration**	v	P	I, P	I, P	I, P	I	P	I, P
4.2	**Usability** (inc. customised media)	vi	1, 2	3	1, 2	1, 2	1	3	3
4.3	**Support**	v	P, C	I, C	I, C	I,P,C	I, P,C	P, C	I,P,C
4.3	**Timeframe** (days)		Now	1 to 3	5	5	30	Now	Cont.
4.3	**Assessment**	v	S, P	I, S	I, S	I, S, P	I	S, P	S, P
4.3	**Evaluation** (Kirkpatrick)	vii	1, 2	1 to 4	1 to 3	1, 2	2 to 4	3	2 to 4
3.2	**Stakeholders**	v	S	I, S	I, S, P	I, S, P	S	S, P	I, S, P

KEY:

- **(i)** O= Objectivism, Cs= Constructivism.
- **(ii)** 1=Attention, 2=Relevance, 3= Confidence, 4=Satisfaction
- **(iii)** T= Theorist, Pg= Pragmatist, A= Activist, R=Reflector, V = Visual
- **(iv)** 1=Presentation, 2=Demo, 3=Guided, 4=Self-directed, 5=Problem-solving
- **(v)** I= Instructor, P= Peer, S= Self, C=Computer-based
- **(vi)** 1=low, 2=medium, 3=high
- **(vii)** 1=Reaction, 2=Learning, 3= Behaviour, 4=Results

  Cont. = Continuous

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