Nurturing innovation in industrial design: Quantifying innovation propensity in industrial design by means of a novel innovation trait index.

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Nurturing Innovation in Industrial Design

Quantifying Innovation Propensity in
Industrial Design by Means of a Novel
Innovation Trait Index

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Summary

This thesis describes the outcomes achieved by an industrial design school that has for a decade directed the energies of its students and Faculty to the question of innovation and the generation of intellectual property.

Developing a culture of innovation is no easy task. Firstly, there has to be a desire within the organisation to be innovative; secondly, there is the problem of how to identify what constitutes innovation; and finally one has to combat the natural tendency toward risk aversion. Successful industrial design should be, by its very nature, innovative. Therefore, generating a culture of innovation is a vital requirement in the development of a successful industrial designer. Do we know how to stimulate, incubate and nurture innovation? What are the factors that give rise to an innovative mindset? How can this culture of innovation be quantified?

The research was conducted using the grounded theory paradigm involving three distinct phases supported by detailed study of the established literature. Theory was developed by comparing innovation outcomes and by alternating data collection and data analysis. The study examined the effect on innovation propensity resulting from an iterative development of pedagogy. Strategies were developed which led to the creation of a distinctive pedagogical model for the promotion and nurture of innovation in industrial design.

The emerging theory is substantive in that it is developed for a particular area of inquiry in a specific context. A statistical test of project innovation was developed and a psychometric test for the evaluation of innovation propensity employed.

The objective of the thesis is threefold. Firstly, it demonstrates that environment, culture and mindset affect the innovativeness of the industrial designer; secondly, it presents a blueprint for innovation pedagogy in industrial design and finally, it provides a verifiable psychometric measurement tool of innovativeness in industrial design.

Acknowledgements

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Ian Walsh
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Glossary

CAD	Computer Aided Design
CAID	Computer Aided Industrial Design
CNAA	Council for National Academic Awards
CSD	Chartered Society of Designers
CSTAT	Committee on Statistics
IBW	International Business Wales
ICSID	International Council for Societies of Industrial Design
ICT	Information Communication Technology
IPR	Intellectual Property Rights
ITI	Innovation Trait Index
LBIO	Literature Based Innovation Output Approach
OECD	Organisation for Economic Cooperation and Development
QAA	Quality Assurance Agency
RSA	Royal Society for the encouragement of Arts, Manufactures & Commerce
SID	School of Industrial Design
TLA	Teaching, Learning and Assessment
WDA	Welsh Development Agency
WPSTI	Working Party on Science, Technology and Innovation Statistics

1 Introduction

"He has filled them with skill to do all kinds of work as craftsmen, designers, embroiderers in blue, purple and scarlet yarn and fine linen, and weavers— all of them master craftsmen and designers."

(Exodus 35:35)

1.1 Background

It is fundamental to our nature to organise, create and implement change. Design as an activity is something we all undertake in our daily lives. We decide our own style, arrange the furniture in our rooms, and plan our daily schedules. These are routine tasks that require processes similar to design. However, design activities are more visible in the creative professions such as art, architecture, engineering, graphic design, and industrial design. Whilst there may be some dispute about the precise definition of the term 'design', it is recognised as a purposeful and creative activity. Design seeks to create things with the purpose of satisfying certain requirements in new ways. In industrial design, a variety of requirements must be considered ranging from functionality and usability to pleasure and self fulfilment.

Design is more than just translating a set of specified requirements into a product; it involves discovering and exploring new requirements. Thus, design involves finding problems and solutions simultaneously, and this is where creativity is important. In recent years a number of studies have taken place with the aim of identifying and understanding aspects of creativity in design (Candy and Edmonds 1996; Christiaans and Dorst 1992; Goldschmidt and Tatsa 2005). These studies suggest that creative designing involves movement from one 'solution space' to another. According to Cross (1997), this is what characterises creative design as exploration, rather than a narrow search for a specific solution. Design exploration can be performed in many different ways. Some designers, especially those interested in the visual composition of objects, explore designs according to guiding principles of composition (Stiny 2006). Recent studies have shown that personal cognitive processes, such as perception and thinking, contribute to the designers' ability to explore designs (Oxman 2002). Smithers (2001) suggests that design exploration should be understood as a personal activity situated in the context and conditions of the designer and design requirements. This, however, seems a rather introverted and esoteric view of design and the designer. Industrial Design has a purpose which is external to the designer. Here the designer acts as interpreter or translator of technology, bridging the divide between function, form and human perception. The designer acts to make the incomprehensible comprehensible by making the potential of technical innovation accessible to its beneficiaries.

1.2 Aims

The genesis of this thesis was the vision to create a community of undergraduates whose innovative design proposals would contribute to the body of knowledge and ascribe value to the generated intellectual property. Since the launch of the Industrial/Product Design programme at Swansea Institute in September 1992 much work had been undertaken to stimulate the creativity of the student body. By the summer of 1997 there was recognition by the programme team that, whilst academic results were satisfactory, the outcomes failed to deliver any truly innovative solutions. Much of the work was conservative and failed to address opportunities that were present to challenge the technological or physical status quo (Walsh and Clement, 2001). The imperative to increase the students' level of innovativeness was established and work began on developing a clear understanding of the nature of the innovation process and the need to reconcile the tensions between delivering a first-class higher education experience with a programme which was of necessity experimental. The object of the research is contextualised within the industrial design education process. It should rightly be expected that industrial design by its very nature should be innovative. The reality is that much of it, though creative and inventive, is not innovative. In industry commercial imperatives often result in innovation being marginalised in favour of a more pragmatic approach to new product development. Research indicates that companies who follow a policy of rapid imitation can be just as successful as companies following a first-to-market innovation strategy (Walsh et al 1992). The assumption that industrial design programmes produce innovative graduates needs to be challenged in much the same way that business recognised the need to make management and marketing more innovative in the 1990s. Industrial designers are often resistant to prescriptive design and innovation methods. They prefer an open methodology which encourages creativity and self-expression often at the expense of true innovation. Arguably the most comprehensive study and discourse on design methods was published by John Chris Jones in his book 'Design Methods: seeds of human futures' (Jones 1970). In this seminal text Jones argues for a greater application of systematic design methods to achieve a truly integrated process of designing. Jones' defines design as 'the initiation of change in man-made things'– a definition which implies that design covers the whole life-cycle of man-made products and systems. This leads us to consider innovation in the same context. If innovation is to become systemic in industrial design then pedagogical methods for nurturing innovation have to be developed.

This thesis concerns how individuals generate innovation in industrial design. It makes reference to cognitive processes in designing but the emphasis is on creating a pedagogical model to nurture innovativeness in undergraduate industrial designers and measure the efficacy of the generated pedagogy in developing both innovativeness and innovation.

1.3 Objectives

The goal of this research is to provide a pedagogical model able to increase the propensity of industrial designers to innovate. This leads first to an examination of the characteristics which constitute an innovative environment, culture and mindset; secondly to describing the means by which innovativeness may be nurtured; and finally to considering the means whereby innovativeness may be quantified. The objective of the presented model is twofold: (i) to demonstrate that environment, culture and mindset affect the innovativeness of the industrial designer, and (ii) to provide a measurement tool of innovativeness in industrial design.

This thesis focuses on industrial design; however, it is argued that the applications of the presented model are not only limited to products but may include design innovation in other disciplines, such as architecture and graphic design.

1.4 Method and Scope of the Study

The chosen research method at the heart of this thesis is based upon grounded theory described by Glaser and Strauss (1967), Glaser (1992) and Glaser (1998). The approach is pragmatic and, unlike more traditional research paradigms, grounded theory research does not attempt to verify existing theory through the testing of hypothesis. Rather, it is an inductive methodology for generating theory. Constant comparison is at the heart of the process, which alternates data collection and data analysis. Before any hypotheses are defined, data is collected, coded and arranged into theoretical concepts. Working hypothesis are defined based upon an analysis of the data to provide a basis for the next stage of data collection.

The research was conducted in three distinct phases supported by a detailed study of the established literature. The literature itself forms part of the data-set and is analysed along with the observed data. Conducted over a period of ten years the study examined the effect on innovation propensity resulting from a systematic development of pedagogy. The developed theory is substantive in that it is developed for a particular area of inquiry in a specific context. The study was initiated during 1997 with a major review and development of a new Product Design programme at Swansea Institute. Following an initial three-year period the programme structure was revised and the impact on innovation assessed. With the objective being to develop new theories of industrial design innovation pedagogy and curriculum development, various data gathering methods were adopted. The traditional requirement of an exhaustive review of literature prior to development of the study was not desirable in this case. It is not that grounded theory research requires no familiarity with the established literature but an over-reliance on related theory can inhibit the researcher's ability to generate theory from the observed data, (Gehrke and Parker 1982). As the study progressed, a careful search of the literature was undertaken to cross-reference the outcomes from the recorded study. The theoretical insights of professionals and academics in the fields of innovation and industrial design were used to support the development of new theory. Glaser and Strauss (1967) comment: "Beyond the decisions concerning initial collection of data, further collection cannot be planned in advance of emerging theory. The emerging theory points to the next step, the researcher doesn't know them until he/she is guided by emerging gaps in their theory and by research questions suggested by previous iterations." Following the initial review and programme development, further iterations followed and the outcomes were evaluated to determine the degree to which the propensity towards innovation presented by undergraduates of the programme changed. Unlike traditional research, where data is all gathered first and then analysed later, the process for generating grounded theory alternates between data gathering and data analysis. Analysis of one phase of data may produce tentative hypotheses that can send the researcher back for more data to verify, expand or modify the initial hypothesis. The extended time frame for the study allowed for periods of reflection where data gathering was suspended in order that data could be analysed and categorised to form theory. Data gathering was continued, but now it was informed by the analysis of previous data. This constant return to the data set illustrates how verification is built into the theory-generating system, although that verification may not be psychometric in nature. Glaser and Strauss strongly objected to using tests for statistical significance in the identification of categories, properties and interrelationships, (Glasser and Strauss 1967). At the heart of grounded theory generation is the constant comparative method of data analysis. As categories emerge they are integrated and relationships are identified. The emergent theory is inductive in nature and very much a theory in process as it has developed from examination of the particular situation in which it is most likely to be used.

As the research progressed new grounded theory was implemented in successive phases of curriculum development. Taking Beauchamp (1982) as a basis, curriculum theory development was addressed in two primary areas: curriculum design and curriculum engineering. Design questions include what should be taught, what form it should take and what scope it should have. Engineering questions focus on how the curriculum is planned, implemented and evaluated. Developments in curriculum and pedagogy are driven by the imperative to ensure that the emerging theory fits the context and that it works.

In the third phase the outcomes were analysed both qualitatively and quantitatively using a number of statistical tools and the results are here reported.

1.5 Structure of the Study

The study assumed the following structure, the initial starting point being the question, 'what makes industrial design innovative?' The resulting research project developed through four phases over ten years. It should be noted that the position of literature in the study is at variance with a more traditional research model. Literature is considered as data with the same status as other observed data within the study. In an emergent study one can begin collecting data immediately. Literature is then accessed as it becomes relevant to the progress of the research. Glaser (1978) highlights the danger of background reading constraining the researcher's ability to read the observed data for emergent theory. Thus the position of literature in the first three chapters of the thesis is as data to be observed and analysed in conjunction with the pedagogical review so as to identify emergent grounded theory.

A STUDY OF INNOVATION PEDAGOGY – PHASE 0

- REVIEW OF PEDAGOGY
- REVIEW OF PROGRAMME STRUCTURE
- REVIEW OF STUDY ENVIRONMENT
- ANALYSIS OF INNOVATION OUTCOMES
- DEVELOPMENT OF A REVISED PEDAGOGY

REVIEW OF INNOVATION RESEARCH

- INNOVATION THEORY
- INNOVATION ENVIRONMENT
- INNOVATION MINDSET
- INNOVATION CULTURE

INDUSTRIAL DESIGN

- INDUSTRIAL DESIGN DEFINED
- INDUSTRIAL DESIGN PRACTICE
- INDUSTRIAL DESIGN PROCESS

DEVELOPMENT OF INNOVATION PEDAGOGY - PHASE 1 (1997-2000)

- IMPLEMENTATION OF NEW PEDAGOGY FOR INNOVATION
- NEW MODULAR STRUCTURE
- NEW STUDY ENVIRONMENT
- INNOVATION OUTCOMES
- REVIEW OF PEDAGOGY
- REVIEW OF PROGRAMME STRUCTURE
- REVIEW OF STUDY ENVIRONMENT
- DEVELOPMENT OF A REVISED PEDAGOGY

DEVELOPMENT OF INNOVATION PEDAGOGY PHASE 2 (2000-2004)

- IMPLEMENTATION OF A NEW PEDAGOGY
- NEW MODULAR STRUCTURE
- INNOVATION CULTURE
- INNOVATION OUTCOMES
- MODULE REVIEW
- CHANGES IMPLEMENTED AS A RESULT OF THE REVIEW

DEVELOPMENT OF INNOVATION PEDAGOGY PHASE 3 (2004-2007)

- IMPLEMENTATION OF NEW PEDAGOGY
- NEW MODULAR STRUCTURE
- INNOVATION MINDSET
    - Student Research Outputs
    - Generated Intellectual Property
    - Peer Recognition – Innovation Awards
- INNOVATION OUTCOMES
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- ITI PSYCHOMETRIC TEST OF U/G STUDENTS
  - Industrial Designers
  - Automotive Designers
  - Engineering Graduates
  - Known Innovators

1.6 Structure of the Thesis

The thesis has been structured into three parts (Figure 1.1). Part A provides a thorough background review of innovation theory, industrial design and the outcomes of Phase 0, a review of the industrial design programme prior to 1997. Part B describes the unique contribution to knowledge derived from the three-phase development of industrial design pedagogy undertaken at Swansea Institute. The study covers the unique nature of the Swansea model of industrial design innovation and the measurement of the innovation outcomes. Part C describes the development of a measurement tool for innovation – the Innovation Trait Index. Chapters discussing the results and drawing conclusions follow before the thesis is completed with a description of proposed future work.

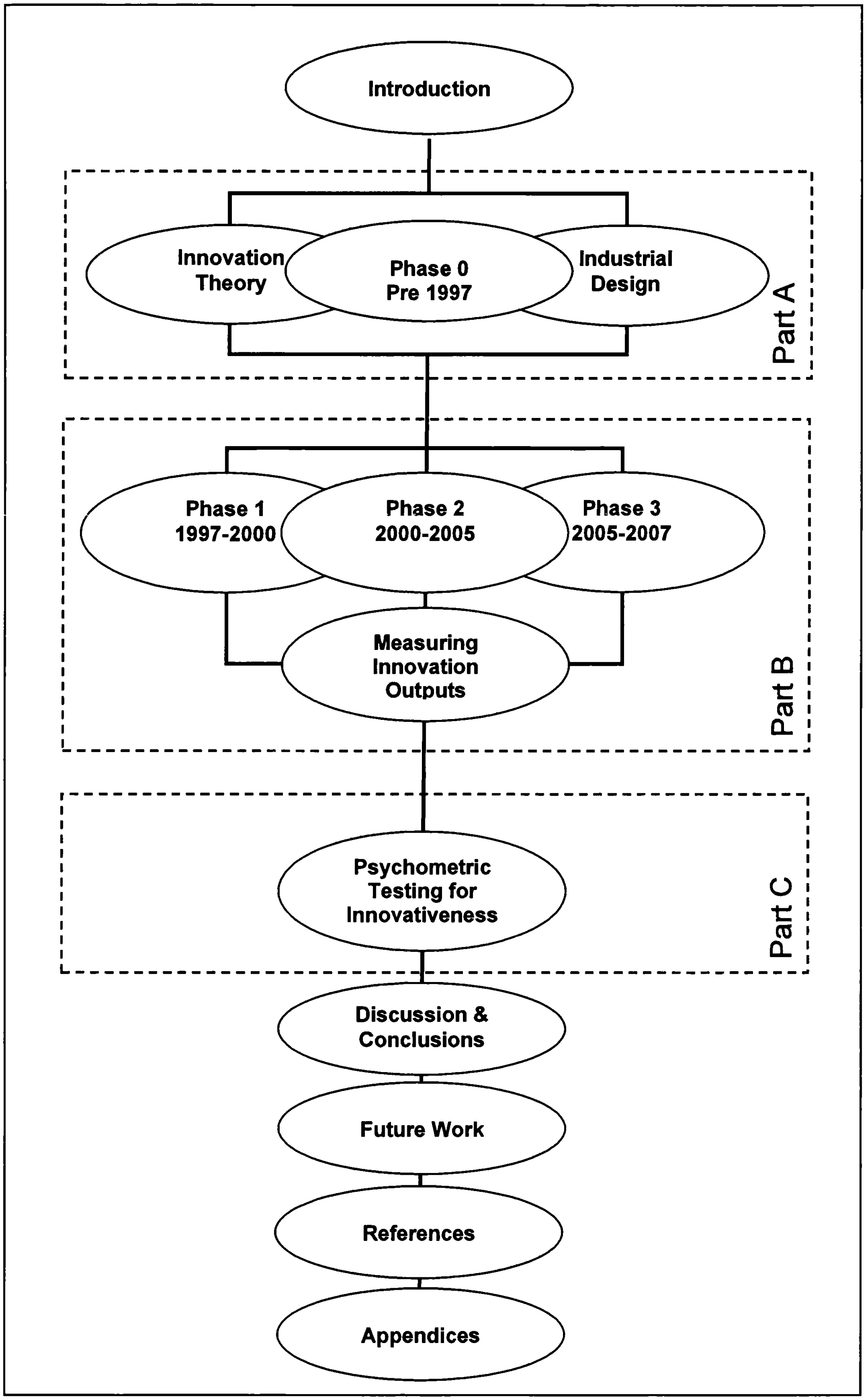


Figure 1.1 Thesis Structure

2 Review of Innovation Research

Innovation has nothing to do with how many R&D dollars you have. When Apple came up with the Mac, IBM was spending at least 100 times more on R&D. It's not about money. It's about the people you have, how you're led, and how much you get it.

(Steve Jobs, 1998)

2.1 Introduction

Innovation research has progressed and advanced significantly over recent years. It has shed light upon a number of factors at three levels of analysis – the individual, the work group, and the organisation more widely. These have consistently been found to be supportive or inhibitive of innovative outcomes (Zaltman, Duncan, & Holbeck, 1973; Amabile, 1988; Van de Ven et al, 1989; King, 1990; West, 1990; Anderson & King, 1993; West, 2001, 2002 King & Anderson, 2002). Considerably more research has been conducted at the individual and organisational levels of analysis, than at the level of the workgroup or ad hoc team. This shortfall in the coverage of innovation research is lamentable especially given the increasingly widespread use of teamwork in organisations.

This chapter focuses on the theoretical, organisational and interpersonal contexts which facilitate the encouragement of innovation generation. Organisations do not only provide the context for innovation to arise – they can also initiate actions to stimulate and inhibit innovation. Such actions can include configuring or structuring an organisation or parts of the organisation in a particular way; they can also include creating posts or roles within an organisation that will assist innovation. They can encourage behaviour likely to foster and nurture innovation. Lastly, they can establish the physical environment suitable for the stimulation of creativity and innovation.

Any review of innovation must commence by establishing a clear definition of innovation within the context of its reduction to practice. This chapter examines several key concepts as they relate to deriving a definition of innovation. It includes the nature of creativity: the conception, adoption and implementation of new services or ideas. 'To innovate' is a verb and therefore implies an action or activity. In this case the action or activity is to design products, systems or services manufactured or conditioned by industry.

The Oxford English Dictionary (OED), (http://dictionary.oed.com), defines 'innovation' as:

'The action of innovating; the introduction of novelties; the alteration of what is established by the introduction of new elements or forms. Formerly const. of (the thing altered or introduced).'

Its origins can be traced back to the 13th century,

[ad. L. innovātiōn-em, n. of action f. innovāre to INNOVATE: cf. F. innovation (1297 in Hatz.-Darm.).]

Various contextualised definitions of innovations exist, all of which exhibit common themes based on the notions of novelty and change as defined by the OED. Myers and Marquis (1969) defined innovation as "the complex idea that proceeds from the conceptualisation of a new idea to the solution of the problem and then to the actual utilisation of the economic and/or social value". The key words that emerge from this definition are 'novelty', 'solution' and 'utilisation'. The importance of these three elements is in the way they elevate innovation above invention. True innovation is the sum of a matrix of parts. It is not just conception, invention or the development of a new market; rather it is all of these factors acting in unison. Zaltman et al (1973) defined innovation as "any idea, practice, or material artefact perceived to be new by the relevant unit of adoption". Here we see the emergence of relativism in the discussion of innovation. Zaltman et al introduces the perception of innovativeness as being critical to developing an understanding of innovation. Drucker (1985) introduced the concept of systematic and planned innovation. He defined innovation as "the purposeful organised search for changes, and systematic analysis of the opportunities such changes offer for economic and social innovation". The nature of innovation can therefore be summarised as follows: "The intentional introduction and application within a role, group or organisation of ideas, processes, products or procedures, new to the relevant unit of adoption, designed to significantly benefit the individual, the group, organisation or wider society." (West and Farr 1990). Within this definition the role of design emerges as a factor – though the exact definition of design in the context of this study is the subject of chapter 3.

2.2 Innovation Theory

The nature of innovation, or rather what constitutes innovation, has been the subject of fairly exhaustive study in recent years.

From the literature we can identify two main schools of thought or interpretations. The first consists of an analysis of the economic changes resulting from a period of innovative activity. These changes may be deduced by comparing the change in state of the economy before and after the change has been effected. In this first approach a number of assumptions are made:

- The innovation considered is fully developed and clearly defined with no further refinement required.
- The innovation is assimilated into a predetermined productive structure.
- The end result of the innovation is a fully evolved state having been shaped by the introduction and implementation of the given innovation.

In the latter half of the 20th century, a new approach emerged based upon detailed and extensive research into specific innovations and patterns of industrial transformation and regeneration. This new approach challenges two of the assumptions made by the more traditional approach. These are:

- That the innovation, whether it is based on technological or human factors, is not fully defined at the point of introduction of reduction to practice.
- That the development of the innovation is not isolated, to emerge perfected at the point of introduction, but rather it develops in a specific environmental context and is shaped by that context, both in the development phase and the implementation phase.

The latter approach is clearly a departure from the traditional static assumptions where innovation was seen as a discrete element of a business. The new, more enlightened, approach was postulated by key figures such as Joseph Schumpeter (1883-1950), the Austrian economist and political scientist. Schumpeter (1934) highlighted the fundamentally uncertain characteristics of the innovation process, when innovators have no predetermined knowledge of the outcome of their activity. Lange (1943) gave a focused interpretation of the nature of innovation. He reduced it to a process of incremental improvements to a production system in a manufacturing firm with a view to maximising the financial return under given market conditions. For Schumpeter (1947) innovation was a function of the entrepreneur in that, "the defining characteristic [of an entrepreneur] is simply the doing of new things or the doing of things that are already done in a new way (innovation)".

This new awareness opened up the debate by encouraging the study of innovation as an ongoing process or narrative rather than a conclusion. Innovation in this model becomes an iterative process or a conveyor belt of invention applied in a given context. The process then becomes a sequential series of actions and reactions with the ultimate evaluation being simply a 'snap-shot' in time. Having established a definition, it is important to note that the contemporary paradigm of innovation as being contextual and dependent on its being new to the relevant unit of adoption leads inevitably to the notion that there are different innovation processes. Arguably the most significant work in this area was carried out by Rogers (1983). These processes can be broadly defined as Individual Level Innovation and Organisational Level Innovation.

2.2.1 Individual Level Innovation

Rogers (1983) identified five stages to individual level innovation:

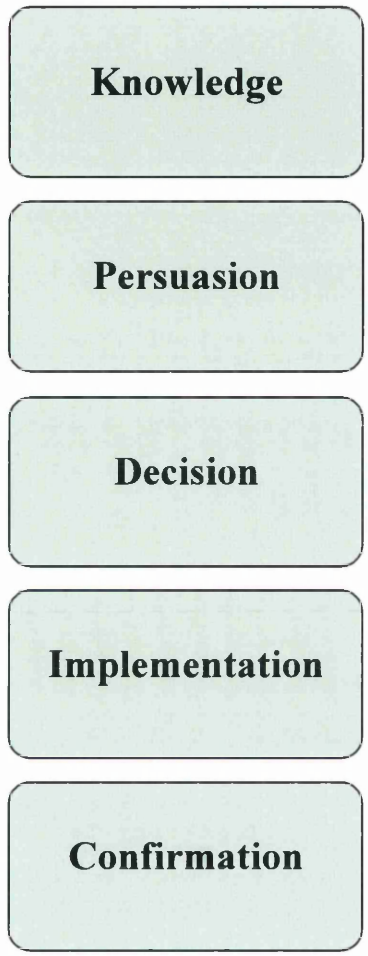


Figure 2.1 Rogers' Five Stages of Individual Innovation

These five stages offer us an insight into the nature of individual innovation. As we analyse each stage it becomes clear that each individual innovator and each individual innovation is the product of a complex matrix of influences.

Knowledge Stage

How does the individual recognise the need or opportunity for innovation? Which comes first – the need for innovation or awareness of an innovation? These questions arise out of man's propensity for selective exposure (Hassinger, 1959). Selective exposure is the notion that the information we are exposed to has little effect unless we perceive it to be relevant to our needs or context. This results in a filtering out of messages which we perceive to be irrelevant to our interests or beliefs, a process known as selective perception. In this state of mind we often 'overlook' opportunities for innovation and fail to recognise potential solutions to needs. The inverse to this is also apparent when we see and recognise an innovation and a need for that innovation develops in response. So our knowledge of innovation is largely dependent on perception. Bright (1969) asserts that our knowledge of innovation follows on from these two ways of seeing. One is by observation and identification of an opportunity or need and the other is by suggestion and/or discovery by scientists and crafts people pursuing their activities. Knowledge of an innovation can be broken down into three distinct areas or domains.

- Awareness knowledge
- How-to knowledge
- Principles knowledge

Awareness knowledge (awareness of the existence of the innovation) leads to how-to knowledge (knowledge of how to use the innovation) which in turn leads to principles knowledge (knowledge of the underlying principles which govern the operation or function of the innovation). Successful innovators or 'change agents' need to understand the three domains of knowledge governing the innovation if they are to facilitate change or bring about a new innovation.

Persuasion Stage

This second stage is linked to the earlier notion of selective exposure. At this stage the individual actively seeks to embrace the innovation or innovative process. It is knowledge dependent and results in behavioural change. The individual will either accept or reject the innovation. Innovations are adopted for one of two reasons: either preventative (in the case where the individual adopts the innovation in order to negate a perceived negative outcome) or positive (where the individual adopts the innovation to accomplish a positive outcome). Overcoming resistance to innovation is crucial in determining the success of innovative processes generally, since acceptance can be hindered by both passive and active resistance (Zaltman et al, 1973). Persuasion rests on the capacity of an individual to cause changes in another's behaviour by the use of more subtle, informal, and often cognitively oriented means than those associated with sanction or authority (Fidler & Johnson, 1984). In using persuasion, an individual communicates evidence, arguments, and a rationale advocating acceptance of an innovative idea and participation in an innovation. Since effective persuasion results in greater participation in the implementation of innovations, it usually entails less resistance to the eventual implementation of innovations and is more likely to ensure active involvement (Johnson et al, 1995).

Decision Stage

The decision stage is inextricably linked to the preceding stages of knowledge and persuasion. The decision stage is typically predicated on the basis of a trial or evaluation of the innovation by the innovator and/or their peer group. Decisions on innovation adoption or rejection are made individually (by an individual acting independently of the organisation or team), collectively (decisions taken by consensus within a team or organisation), or authoritatively (decisions taken by a relatively small group in a system which possesses authority or technical expertise).

Implementation Stage

Key to understanding the difference between invention and innovation is the implementation stage. Implementation is the reduction to practice of the inventive concept. Without implementation innovation can not be said to have occurred. The implementation stage is critical in the chain of events which comprise the five stages of individual innovation. At this stage uncertainty regarding the potential consequences of the innovation remains. Problems of implementation can be exacerbated when the unit of adoption is an organisation rather than an individual. In situations where the originators of the innovation are a different group from the decision makers, problems of communication and understanding can undermine the potential benefits of the innovation. In the case of industrial design it is common for this case to exist. Industrial design practitioners typically work in consultancies remote from the decision-making centres of the unit of adoption. Even where the industrial design function is embedded in a business it is rare for the industrial designers to be the decision makers in the implementation stage. Focus-group testing and an array of test methodologies are adopted to pre-empt potential problems associated with implementation, to reduce the likelihood of rejection or failure.

Confirmation Stage

Post-adoption confirmation is the fifth and final stage of Rogers' innovation model – seeking reinforcement for the decision process already made by reviewing the implementation through feedback mechanisms. Feedback mechanisms include observation by electronic or human agents. Remote monitoring of the innovation provides measurable data to confirm the benefits of the innovation. Interviews and behavioural observations of user interaction provide valuable insights into the degree of satisfaction engendered by the innovation.

2.2.2 Organisational Level Innovation

As previously stated, the innovation decision process falls in to three distinct decision types:

- Optional innovation – decisions, made by an individual.
- Collective innovation – decisions, made by a group.
- Authoritative innovation – decisions, made by those with power, status or expertise.

In the context of innovation the focus of organisations is on collective- and authoritative-based innovations. Unlike individual level innovation the innovation decision-making process within organisations is governed by complex relationships between often competing elements and interests within the organisation. The nature of the innovative environment is discussed in detail later in the thesis (2.3). As with individual innovation, there are five identifiable stages to organisational innovation. Each stage is characterised by a particular range of events, actions and decisions. The following diagram (figure 2-2) summarises Rogers' five-stage model.

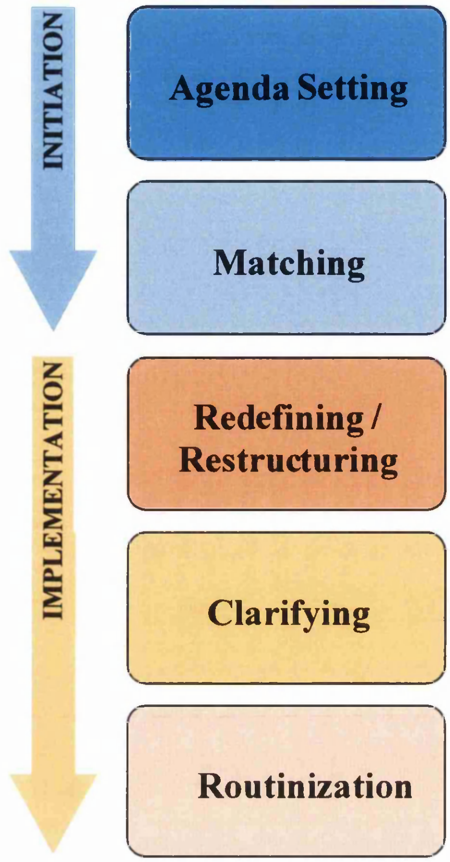


Figure 2.2 Rogers' Five-stage Model for Organisational Innovation

Rogers divided the organisational innovation model into five stages grouped into two phases of innovation: initiation and implementation.

Initiation – Agenda Setting

Agenda setting is the continuous process of strategic and motivational goal setting which forms the catalyst for the latter stages of innovation to occur within the organisation. It is at this stage that problems affecting the organisation or sphere of activity are defined and the need for innovation identified. At a strategic level, organisations may search for innovations outside their sphere of activity and seek to import the innovation and re-interpret the innovation in the interests of their particular organisation.

Initiation – Matching

Problems and innovations are matched to determine the best possible fit. The innovation may be 'off the shelf' or bespoke. In either case, the implementation of the innovation requires design and planning.

Implementation – Redefining / Restructuring

The implementation of any major innovation, whether in terms of operational practice or product introduction, requires a degree of reinvention of the innovation to accommodate the particular needs and structure of the organisation. Alternatively the organisation may need to be restructured to facilitate the introduction of the innovation. This often results in the creation of a new organisational unit – for example, a 'spin-out' company.

Implementation – Clarifying

At this critical stage, the relationship between the organisation and the newly introduced innovation is clarified and defined more clearly. The pace of adoption is a significant element in the innovation's adoption or reduction to practice. Too quick, and the organisation's capacity to absorb the resulting change may prove unmanageable. Too slow, and the organisation may lose the benefits of the innovation. This stage witnesses the acceptance of the innovation into the organisation's structure and practice.

Implementation – Routinization

In this final stage the innovation loses its separate identity and becomes an element in the organisation's ongoing activities. From this point forward the innovation ceases to be new as it is absorbed into the procedural norms of the organisation. In product innovation this stage is also known as the 'proliferation stage', where technological innovations are embedded or adapted for use across new markets. Withdrawal or discontinuance of an innovation can still occur even at this late stage if its performance is seen to be unsatisfactory.

This linear, generic innovation process model is in reality an academic over-simplification as in reality the true picture is of a highly complex socio-economic, socio-cultural and technical process in which the stages are indistinct and often do not follow the sequence identified in the literature, (Bright, 1969).

2.2.3 Non-linear Innovation

As a counter to the conventional stage-based models a number of authors have proposed alternative non-linear approaches and their aim of normalising the innovation process. King (1992) identified the dangers of placing too much confidence in the normative approach. Schroeder et al (1989) proposed a model comprised of a series of six characteristics of the innovation process.

- Innovation is stimulated by shocks, either internal or external.
- An initial idea tends to proliferate into several ideas.
- Unpredictable setbacks and surprises are inevitable; learning occurs whenever the innovation continues to develop.
- As an innovation develops, the old and the new exist concurrently and over time they are linked together.
- Restructuring of the organisation during the innovation process.
- Hands-on top management involvement occurs throughout the process.

Another weakness with normative models of innovation is their failure to fully acknowledge the impact of perception on the innovation process (Aydin and Rice 1991). A further argument against the stage-based model is the fact that the innovation process may develop differently depending on the nature and context of the innovation. Pelz (1983) found that radical innovations were less likely to be the product of linear innovation strategies than less radical innovations. Sauer and Anderson (1992) found that innovations introduced to an organisation from outside involved a far more complicated pattern of development than in-house innovations. These cases indicate that innovation culture and environment are significant determinants in innovation genesis and that an innovation mindset is as important as management strategy in bringing about successful innovation.

2.3 *Innovation Environment*

Organisational or corporate culture refers to the internal workings of an organisation. Just as the culture of a country affects things like attitudes to work, attitudes to and the use of authority, equality and styles of decision-making, so organisational or corporate culture influences and affects the process of innovation. Since some organisations appear to be better at innovation than others, there is a case for suggesting that corporate culture can both encourage and discourage innovation at the individual and organisational level.

What is organisational or corporate culture? It is the internal context of an organisation. At the most simplistic level corporate culture is simply 'the way we do things around here'. Corporate culture manifests itself in a variety of ways. It comprises the shared values and beliefs of those working in the organisation in the sense of a common, often tacit, understanding of what is considered important within the organisation. Physical objects such as prestigious offices and company cars can act as powerful symbols of corporate culture. Rarely is an organisation's corporate culture formally laid down or defined by precept. Typically it rests on shared assumptions about ways of behaving, about decision-making and about what is important to the organisation – a spirit.

Charles Handy (1993) provides an interesting perspective on corporate culture by classifying corporate cultures into four broad types. The categorisation is not meant to be exhaustive but it does help to illustrate how corporate cultures can differ. According to Handy four recognisable cultures are:

- Power culture
- Role culture
- Task culture
- Personal culture

Organisations with a **power culture** are typically ones led by a strong individual able to firmly stamp his or her ideas on the organisation and the way in which it does things. Power cultures often give rise to ad hoc decision-making processes, with power and authority centred on a single individual, usually the chief executive. Power cultures are often associated with organisations founded and run by a successful and charismatic entrepreneur. The strength of this form of organisation is its dynamism and propensity towards rapid decision-making. A weakness is its reliance on a single powerful individual.

A **role culture** in contrast is highly hierarchical and formulaic with well defined, rational decision-making processes, highly structured relationships and formal rules and procedures. In general, role cultures are usually associated with large organisations that rely on a high degree of formality and associated accountability. This can lead to bureaucratic paralysis and be detrimental to innovation.

Task cultures, as their name implies, are task oriented with people and systems working together to achieve an objective or solve a problem. Team working is a key feature of such cultures with people working closely together towards collectively agreed goals. A task culture is typically characterised by informality not only in terms of how people dress and communicate with one another, but also in terms of how they relate to each other and how they make decisions.

Organisations that exhibit a **personal culture** place a strong emphasis on individuals and personalities. Individual knowledge and expertise tend to be highly valued. The negative side to this form of organisation is that decision-making is not always easy and is not always consistent.

Since organisational and corporate culture influences the internal context of an organisation, it can have a significant impact on innovation. Some corporate cultures are generally more conducive to innovation than others. This is not to say that there are certain cultures that guarantee innovation, as the drive for innovation has to come from individuals or groups of individuals. Rather it is the case that, if the potential for innovation is present, then it is more likely to thrive in some organisational cultures than others. Of the four types of corporate culture put forward by Handy it is unclear which of the cultures described is more conducive to innovation than any other. A role culture is unlikely to help foster innovation. On the other hand, a personal culture, while it won't necessarily produce innovations, may well be an environment in which new ideas can thrive.

The literature is littered with attempts to define the optimum innovation culture. According to Smith (2006) organisations with a strong record of innovation will have a corporate culture that is:

- Outward looking and receptive to new ideas, particularly from outside;
- Facilitates communication, especially across the organisation;
- Is open and receptive to new ideas and approaches;
- Challenges established ideas and practices – 'the conventional wisdom';
- Accepts and learns from failure;
- Promotes evaluation and reflection.

Establishing the optimum working environment in order that innovation may be facilitated requires careful consideration and application. There are numerous environmental factors which affect innovation. These can be internal or external to the organisation. They can be controllable or uncontrollable. Identifying the variables and managing their impact on the environment is strategically highly important. The nature of the work or managerial environment can present the potential innovator with a series of negative or positive factors of influence. King (1987) identified the most significant factors as being:

- Organisational structure
- Organisational strategy, culture and climate
- Organisational size
- Organisational resources
- Organisational knowledge of innovations

Organisational structure refers to the physical assets of the business along with the less tangible aspects of the business such as status, structure and management structure. Once more King (1987) refers to three characteristics of organisational structure which have an impact on innovation:

- Centralisation of authority
- Formalisation of roles and rules of behaviour
- Complexity of roles

Organisational strategy refers to the policy and attitudes within the organisation. Organisational culture and climate interact with structure and strategy to affect organisational innovation. Highly structured organisations are termed 'positional companies' and have a strong emphasis on stability and status quo. Highly strategy oriented organisations are called innovative companies as their emphasis is on innovative strategy and the need for radical change. Organisational structure establishes the environment within which innovation has to exist. Organisational culture and climate may inhibit or promote innovation: culture by the values, norms beliefs and assumptions embraced by the organisation and climate by the 'atmosphere' prevalent within the organisation. Climate may be defined as the way the organisation's culture is expressed at any given point in time.

2.4 Innovation Mindset

2.4.1 Introduction

An innovation mindset can be characterised as a pervasive spirit that stimulates individuals and teams to strive to create and adopt new approaches across the entire organisation. An innovation mindset is an attitude, a state of mind, which should permeate the entire institution. The hallmarks of this mindset can be seen in the way individuals at all levels in the organisation interface with each other. Kuczmarski (1996) noted:

"You know a company with an innovation mindset when you see the way employees interact with one another. They treat one another with respect, admiration, and cooperation. They smile. They laugh. They express consideration and thoughtfulness. They listen. They focus on the benefits desired by consumers rather than on their own personal gain. They come to work with an optimistic enthusiasm, because they believe that what they do each day really does count. They focus on the future rather than on the past. They exude self-confidence, possess a healthy self-esteem, and believe in their own capabilities and strengths. They have faith in innovation and in one another."

Achieving this state and sustaining it is at the heart of this thesis. If an organisation is sincere in its ambitions to be innovative then an innovative mindset must be evident throughout the entire structure. Developing an innovative culture, as has been identified in 2.3, is not easy. How can a managing director, CEO or head of an academic centre begin to create such a culture? The answer is that in most cases they do not even try. This is not because they do not realise the importance of innovation but rather they become discouraged. The first step in creating an innovative mindset within the organisation as a whole is for those who manage the organisation to begin to believe in the benefits of innovation and then, once the true importance of innovation has been recognised and accepted, communicate that passion to the rest of the organisation team. Once this innovation mindset is embedded in the outlook and attitude of even one key manager then the seed of innovation has been sown. Individuals possessing this mindset can, with skill, creativity, insight and determination produce innovative results. For truly radical innovation to flourish, motivated and effectively managed groups of people are required.

In the context of this study, the question that arises is what are the fundamental principles of innovation that could be nurtured in the education experience? Key principles of innovation within an individual and an organisation include curiosity, questioning, experimentation, self-motivation, vision, passion, flexibility, commitment, resilience and perseverance. These principles or qualities can occur 'naturally' but more often require nurturing if they are to become fully employed. The question of how to nurture innovation within an educational environment must be preceded by the question 'why do we need to be innovative?' This can be summarised in the phrase 'to survive and to thrive'. The answer lies in the generation of an innovative mindset amongst undergraduates that will begin to create:

"a pervasive attitude, a feeling, an emotional state, an ongoing commitment to newness. It is a set of values that represents a belief in seeing beyond the present and making that vision a reality."

(Kuczmarski 2003).

2.4.2 Definitions of Innovative Behaviour

Universal agreement on the essence of innovative behaviour has been lacking (Roehrich, 2004). Innovative behaviour is often defined by the data available to the researcher, or by the data which the researcher could obtain at a given time and place. In much of the literature innovation is considered in the context of consumer innovation, i.e. the rate of acceptance and take up by consumers of innovative products or services. In this field there has been much work and there is value in considering it as a model for testing and modelling innovative behaviour in other sectors. In the field of consumer innovation mapping, the three most common forms of definition have been self-report, time-of-adoption and cross-sectional (Goldsmith & Hofacker, 1991).

The self-report approach is based on the presumption that there exists an identifiable trait of innovativeness (Im et al, 2003; Ridgway & Price, 1994). In this model actual behaviour is not measured; instead, innovativeness is measured via a written questionnaire. Roehrich (2004) lists and categorises several innovativeness scales. His first category, the life innovativeness scales, represents scales that measure innovativeness across a number of areas, not just activities in the consumer realm. Scales characteristic of this perspective include those of Leavitt and Walton (1975), Kirton (1976), and Hurt, Joseph, and Cook (1977). Although these scales address the predispositional variables included in the proposed model, they primarily focus on individuals' possession of these qualities regardless of how they may ultimately be manifest. The second category of innovativeness scales proposed by Roehrich (2004), the adoptive innovativeness scale, has been expressly designed to measure innovativeness as a tendency to purchase new products. Scales developed with this perspective include those of Raju (1980), Baumgartner and Steenkamp (1996), and Goldsmith and Hofacker (1991). The predictive ability of these scales is generally significantly greater than the life innovativeness scales. Since the adoptive innovativeness scales were developed to predict new product adoption, the predictive ability is not surprising. These tools were primarily developed to measure the predispositional causes of innovative behaviour. Consequently, these scales expressly exclude the situational variables that may also be manifest via innovative behaviour. Faced with the less than acceptable results from the innovativeness scales, Roehrich (2004) suggests alternative forms of measurements may be preferred. The self-report approach to defining innovative behaviour based on a psychological measuring scale, therefore, does have its problems. Actual innovative behaviour is not measured.
The time-of-adoption approach is based on the length of time between when an innovation first becomes available and when the adoption decision is made (Rogers, 1995). This perspective is based solely on the viewpoint of the change agent, which,

in the instance of innovative behaviour, is the business who has recently introduced an innovation to the marketplace. Venkatraman, (1991), states that this form of measuring innovative behaviour actually "identifies new product adopters, not innovators".

Finally, Midgley and Dowling (1978) recommend the use of a cross-sectional approach where innovative behaviour is measured by the number of products that have been adopted from a list of new products at a given point of time. The need for a listing of various types of products is necessary given that individuals manifesting a motivation for variation via new product adoption often do so in a product-specific manner. The specific new products adopted as a manifestation of a motivation for variation will vary by the source of the motivation and the needs and constraints faced by the individual.

The three innovation behaviour scales outlined above have only limited value in identifying predictive models of innovative behaviour. Essentially they were developed to identify innovation adoption patterns in consumers. As a consequence they do not adequately define the nature of innovation origination. For this a new model is required. Goldsmith and Hofacker (1991) identified the three approaches: self-report, time-of-adoption, and cross-sectional. Of these three, the self-report approach offers the greatest potential for success. The approach focuses on the adoption of an innovativeness scale as a mechanism for predicting the potential for innovation of the subject. In the context of this thesis the subject is an industrial design undergraduate and the context is the origination of innovation in new product development. The starting point must be to identify the individual characteristics which define an innovator and then establish a methodology for scaling those characteristics.

2.4.3 Individual Characteristics of an Innovative Mindset

A number of new questions emerge at this point. Are innovators born or created? Can an innovative mindset be developed? At the individual level, are there essential characteristics which define or at least indicate innovative potential? Farr and Ford (1990) compared innovation with a model for individual motivation. They found four general factors which influenced the individual's propensity to innovate:

- Individual's perception about the need for change
- Belief that change can be achieved within the work role
- Belief that a successful outcome will emerge
- The individual's capacity to generate new and useful ideas

Robertson and Kennedy (1968) based upon the work of Everett Rogers (1962) identified a model containing seven distinguishing characteristics that separate innovators from non-innovators:

- **Venturesomeness** – Rogers uses venturesomeness as a summary concept to characterise agricultural innovators. Venturesomeness is operationally defined by Robertson and Kennedy as willingness to take risks in the purchase of new products.

  "The major value of the innovator is venturesomeness. He must desire the hazardous, the rash, the daring, and the risking." (Rogers 1962, p 169)
- **Social Mobility** – Here, upward social mobility is measured and defined by prior and anticipated movement on the social class ladder.
- **Privilegedness** – Here privilegedness is defined as the individual's higher financial standing relative to other community members.
- **Social Integration** – Social integration is defined as the person's degree of participation with other community members.
- **Interest Range** – Drawing on the evidence presented in the literature Robertson and Kennedy suggest that innovators may be committed to a wider range of interests or values than non-innovators.
- **Status Concern** – Status concern is the person's need to be noticed and admired. The variable is not explicitly derived from diffusion research but from Veblen's treatise on conspicuous consumption (Veblen 1912). The conspicuousness of innovations and the resulting attention may prompt innovative behaviour.
- **Cosmopolitanism** – How oriented the person is beyond their community is referred to as cosmopolitanism.

Ditkoff (2003) proposed 20 qualities common to the innovative mindset:

- **Challenges status quo** – dissatisfied with current reality, questions authority and routine and confronts assumptions.
- **Curious** – actively explores the environment, investigates new possibilities, and honours the sense of awe and wonder.
- **Self-motivated** – responds to deep inner needs, proactively initiates new projects, intrinsically rewarded for effort.
- **Visionary** – highly imaginative, maintains a future orientation, thinks in mental pictures.
- **Entertains the fantastic** – conjures outrageous scenarios, sees possibilities within the seemingly impossible, honours dreams and daydreams.
- **Takes risks** – goes beyond the comfort zone, experimental and non-conforming, courageously willing to 'fail'.
- **Peripatetic** – changes work environments as needed; wanders, walks or travels to inspire fresh thinking; given to movement and interaction.
- **Playful/humorous** – appreciates incongruities and surprise, able to appear foolish and child-like, laughs easily and often.
- **Self-accepting** – withholds compulsive criticism of their own ideas, understands 'perfection is the enemy of the good', unattached to 'looking good' in the eyes of others.
- **Flexible/adaptive** – open to serendipity and change, able to adjust 'game plan' as needed, entertains multiple ideas and solutions.
- **Makes new connections** – sees relationships between seemingly disconnected elements, synthesises odd combinations, distils unusual ideas down to their underlying principles.
- **Reflective** – incubates on problems and challenges; seeks out states of immersion; ponders, muses and contemplates.
- **Recognises (and re-cognises) patterns** – perceptive and discriminating, notices organising principles and trends, sees (and challenges) the 'big picture'.
- **Tolerates ambiguity** – comfortable with chaos, able to entertain paradox, doesn't settle for the first 'right idea'.

- **Committed to learning** – continually seeks knowledge, synthesises new input quickly, balances information gathering and action.
- **Balances intuition and analysis** – alternates between divergent and convergent thinking; entertains hunches before analysing them; trusts their gut, uses their head.
- **Situationally collaborative** – balances rugged individualism with political savvy, open to coaching and support, rallies organisational support as needed.
- **Formally articulate** – communicates ideas effectively, translates abstract concepts into meaningful language and creates prototypes with ease.
- **Resilient** – bounces back from disappointment, learns quickly from feedback, willing to 'try, try again'.
- **Persevering** – hardworking and persistent, champions new ideas with tenacity, committed to follow-through and bottom-line results.

Whilst Ditkoff provides a useful checklist of the wide range of attributes common to the majority of innovators a degree of rationalisation is required. Farr and Ford, (1990); and Roberts and Kennedy (1968) propose four and seven-point lists respectively which offer some way forward if one is to condense and focus the list of attributes.

2.5 *Innovation Culture*

2.5.1 Introduction

What constitutes an innovation culture? Innovation as a management concept has matured over the past ten years to become something of a management science. But innovations will not just emerge at the behest of a keen manager armed with an MBA; conditions must be established to encourage their emergence. Developing an innovation culture requires the full participation of all stakeholders in the organisation. Being an innovator requires a strategy for growth, combining research with creativity and engineering. In organisations where innovation is constrained to in-process productivity improvements, there is often a limited understanding of the benefits of innovation in gaining competitive advantage. It is tempting to see productivity improvement as a substitute for innovation. Facilitating the development of an innovation culture requires significant changes to the operating culture of the organisation. The 'Innovation Culture Continuum' developed by the Richard Ivey School of Business in Ontario presents one model for the development of such a culture, (Angel 2006).

Foundation	Advanced	Breakthrough	
Hierarchical Command and Control	Departmental Silos	Self-directed Virtual Teams	Management
Transactional and Aggregated	Integration Across the Enterprise	Learning and Service Delivery Architecture	Information
Cost and Risk Reduction	Productivity Improvement	Collaborative Improvement	Operations
Product	Segmented but still Product Based	Customers' Individual Needs and Value	Customers
Growth	Growth and Performance	Innovation	Strategy

Figure 2.3 Innovation Culture Continuum (Angel 2006)

Three levels of performance culture are depicted: 'foundation', 'advanced' and 'breakthrough'. At the foundation level, a hierarchical and risk-focused organisation typically concentrates on transactions, selling more products or services and keeping costs in check. Foundation organisations often try to improve performance by working harder, developing sales skills and targeting selected customers more systematically. They often let go staff of who fall short of performance goals set for them or for the organisation. This approach can work, at least for a while - many foundation organisations have reported steadily improving financial and operating results for extended periods. However, they also build up considerable stress at all levels in the organisation and raise serious long-term questions about both business purpose and sustainability. At the advanced level, an organisation is typically integrating organisational silos, so that individual departments can work with each other to achieve productivity improvements and develop flexibility of response. At the breakthrough level the desired payoff is a competitive advantage that is self-sustaining as the operational environment changes. Organisation-wide self-actualisation leads to an innovative knowledge-intensive culture. Kurato and Hodgetts (1990) identified some of the factors which come together to formulate an innovative culture. They assert that innovation is most likely to occur when the climate is right.

2.5.2 Innovation Climate

Some of the important characteristics of this climate are:

- A trustful management that does not over-control the personnel
- Open channels of communication among all members of the business
- Considerable contact and communication with outsiders
- A willingness to accept change
- An enjoyment of experimenting with new ideas
- Little fear of negative consequences of making a mistake
- The selection and promotion of employees on the basis of merit
- The use of techniques which encourage idea generation, including suggestion systems and brainstorming
- Sufficient financial, managerial, human and time resources for accomplishing goals

The importance of working culture and workplace dynamic has been the subject of much study. The importance is highlighted when one considers the fact that the majority of innovations take place in research and development teams rather than by lone pioneering innovators. The leadership culture is critical if innovation is to flourish.

2.5.3 Negative Attitudes

Kanter (1983) identified a number of negative factors pertinent to area of study.

Negative management attitudes which stifle innovation:

- Regard any new idea from below with suspicion – because it's new and it's from below.
- Insist that people who need your approval to act have to go through several other levels of management to get their signatures.
- Ask departments or individuals to challenge and criticise each other's proposals. (That saves you the job of deciding; you just pick the survivor.)
- Express your criticisms freely and withhold your praise. Let people know they can be fired at any time.
- Treat identification of problems as signs of failure to discourage people from letting you know when something in their area isn't working.
- Make decisions to reorganise or change policies in secret and spring them on people unexpectedly.
- Make sure that requests for information are fully justified and make sure that it is not given out to managers freely.
- Assign to lower level managers, in the name of delegation, responsibility for figuring out how to cut back, move around, or otherwise implement threatening decisions that you have made.
- Never forget that you, the higher-ups, already know everything that is important to know about this business.

2.5.4 Positive Attitudes

The antidote to this negative attitude comes in many forms and has been summarised by Stoner, Gilbert and Freeman, (1995). They proposed a number of ways in which organisational innovation and creativity can be fostered and an innovation culture created. These include:

- Develop an acceptance of change
- Encourage new ideas
- Permit more interaction
- Tolerate failure
- Provide clear objectives and freedom to achieve them
- Offer recognition

These suggestions can be seen to parallel the individual innovative traits discussed in 2.4.3 and backed up by other authors such as Smith, (1998). The primary issue here is one of mindset as defined by Kuczmarski in 2.4.1: "An innovation mindset is an attitude, a state of mind, which should permeate the entire institution."

2.6 Innovationist Roles

2.6.1 Introduction

An innovationist is someone who favours innovation. It is a useful term as it encompasses not only the initiator of the innovation but also the facilitator of innovation and the adopter of innovation. There are a number of roles within organisations which, while not specific to innovation, have been found to contribute to the development of a successful innovation culture. A number of the roles are formal in that they take the form of designated posts, but most are not, carrying no title and no formal designation. They are no less important for that. The roles, both formal and informal, include:

- Project leader
- Product champion
- Gatekeeper
- Godfather

2.6.2 Project Leader

The role of project leaders is a formal one. He or she is likely to be a figurehead, the person probably most closely associated with the project. Their job is to take responsibility for the project and manage it. Obviously project leaders need to have a strong knowledge of the field, but they also need a breadth of knowledge and experience to enable them to co-ordinate and draw together the various functions required to bring an innovation to fruition. The project leader also needs to be a planner, able to methodically chart what needs to be done, by whom and when. Together with the scheduling capability required to do this he or she needs to be able to exercise control by monitoring performance and taking action as necessary.

Thus a project leader is likely to possess a matrix of talents, combining the communicational and motivational skills required to ensure a cohesive and effective multi-disciplinary team with the analytical skills required to ensure effective organisation and management of resources.

2.6.3 Product Champion

Schon (1963) first proposed the concept of the product champion. Numerous field and case studies have found strong support for Schon's contention that innovation success is closely linked with the presence of a champion (e.g. Roberts, 1968; Achilladelis, Jervis, and Robertson, 1971 ; Rothwell et al, 1974; Burgelman, 1983; Ettlie, Bridges, and O'Keefe, 1984). Schon noted how new developments especially innovations within large corporations frequently run into trouble. He argued that there could be a variety of reasons for this. Often the novelty of an innovation challenges 'accepted ways of doing things and long-established skills'. Sometimes senior managers will feel threatened by their lack of knowledge of the technology; sometimes, if changes in technology lead to changes in social organisation, staff will feel threatened by possible potential structural changes. For various reasons innovations often encounter powerful vested interests who see innovation as a threat to the current status quo. Often out of fear such interests will seek to block or at least hinder the innovation, Kanter (1983). As Schon identified, within large organisations the systems and procedures designed to screen new ideas can also provide a series of formidable obstacles to innovation. Requiring levels of detail that it is often very difficult to provide in the early stages of a new development screening procedures can easily act as a deterrent discouraging innovation.

To assist innovative developments through the corporate minefield, Schon proposed the concept of someone who would act as a product or innovation champion doing all in their power to promote the innovation in order to ensure its success. Essentially the role of product champion implies someone who will act as an advocate for the innovation prepared to support and defend it even in the most difficult circumstances.

> *"...the champion must be a man willing to put himself on the line for an idea of doubtful success. He is willing to fail. But he is capable of using any and every means of informal sales and pressure in order to succeed."*
>
> Schon (1963: p84)

To carry out the role, product champions clearly need political support within the organisation. More importantly the product champion has to identify with the innovation. He or she has to be a stakeholder in the innovation to defend and protect its integrity at all times.

2.6.4 Gatekeeper

In the age of knowledge-based economies, the maxim that 'knowledge is power' is evident across most businesses. There is increasing awareness of the importance of knowledge in innovation. Studies have shown that, in particular, it is an organisation's ability to transfer knowledge that leads to innovation. Huang and Lin (2006) identified the essential role that R&D information systems played in the development of innovation. In a study of hi-tech electronics companies in Taiwan it was discovered through case studies and confirmed by an innovation survey that R&D information systems help not only the generation but also the utilisation of technical reports and assist professional knowledge cultivation. In this process individuals play a key part in the networking that forms part of the knowledge transfer. In the process they are acting as gatekeepers.

Individuals taking on this gatekeeper role effectively hold the key to accessing knowledge. Quite how they operate is likely to vary but typically includes:

- Acting as a repository of knowledge
- Knowing who possesses knowledge
- Exercising skill in making connections
- Acting as a 'go-between' for parts of the organisation or between organisations

At the simplest level gatekeepers act as repositories of knowledge. This knowledge is rarely of the formal codified variety; rather it is more likely to be tacit knowledge. Frequently the gatekeeper's actual knowledge is limited. Hence it is not the gatekeeper's knowledge that matters but rather their ability to access and connect with others, specifically those who do possess the necessary specialist knowledge. This is less a matter of knowledge and more a matter of skill, particularly skills in networking with others. It is worth noting that gatekeepers often act as a bridge between different parts of an organisation. Gatekeepers of this type can be very valuable as they can act as a conduit to facilitate knowledge transfer. Allen (1977) in a study of the Apollo space programme noted the importance of communication and information flows to the innovation process and he particularly highlighted not just formal communications but informal communications. The latter were rarely linked to formal positions within an organisation; rather they were a function of individuals who were well placed within the informal structure of the organisation. Allen termed them gatekeepers to pinpoint their role in accessing knowledge.

2.6.5 Godfather

The godfather role is probably the least formal of these four roles. The godfather role is one taken by senior managers, preferably working at board level. The role is essentially one of providing 'behind-the-scenes' support. To be effective a godfather has to be able to exercise power and influence within the organisation. Support can be provided in a variety of ways, but will almost always be exercised internal to the organisation. Support may mean looking out for the innovation and affording it protection, particularly from reactionary forces within the organisation. Such forces might include those who are risk averse, those possessed of a 'not-invented-here' perspective, those who find it difficult to see future potential, or those who regard any new idea from below with suspicion – because it's new and it's from below (Kanter 1983) or those who just see their powerbase threatened. Clearing these hurdles can be difficult in the case of innovations where the market is new or ill-defined or in situations where there are a number of projects all competing for funds. The godfather may be able to help the innovation 'navigate the rapids' of project evaluation, especially if the godfather has inside knowledge of where the worst and most significant obstacles lie. Here the godfather can take a more proactive stance. Typically this might mean removing potential obstacles, be they people or potential hurdles. It might mean providing access to resources. These could be financial, but are probably more likely to be people, equipment or facilities. Finally, a godfather may simply exercise moral support for the innovation team. Difficult to quantify, it may be vitally important in maintaining motivation within the innovation team.

3 Industrial Design

"A good designer has to be part artist, part engineer, psychologist, sociologist, planner, marketing man and communicator: part everything and part nothing!"
(Roberto Pezzetta, 2001)

3.1 Introduction

As previously discussed key principles of innovation within an individual and an organisation include curiosity, questioning, experimentation, self-motivation, vision, passion, flexibility, commitment, resilience and perseverance. These principles or qualities can occur 'naturally' but more often require stimulating if they are to become fully employed. The question of how to stimulate innovation has been the constant thread running through the study. To the academic institution, innovation is vital if it is to remain at the forefront of its discipline. Competition for students and increasing pressure to deliver research or commercial funding mean that the institution must constantly review and re-invent itself to remain relevant and true to its mission. To the undergraduate designer innovation is vital if he/she is to produce a successful major project and portfolio, and compete in what is an increasingly global job market. The role of the academics in accepting and encouraging innovation is vital. The programme structure and assessment criteria need to be conducive to the encouragement and reward of innovation. Stimulating a culture of innovation depends upon all parties being fully committed. The challenge of an academic programme where assessments have to be made and deadlines met is how to create the time to allow for the incubation of innovative ideas. It is vital to encourage the integration of projects across modules and even across year groups. Innovation does not end with the student project itself but must extend to embrace the mode of delivery, assessment and feedback. It would be wrong to conclude that, once established, this culture of innovation can be maintained as a status quo. Indeed, the very nature of this culture is that it is constantly changing. The role of the academics is to ensure that teaching, learning and assessment strategies constantly evolve so as not to frustrate the innovative spirit. Undergraduates need to be able to experiment and challenge the boundaries. It is against this background that this thesis examines the nature and scope of industrial design and its relationship to innovation. In the process the author seeks to demonstrate that due to the nature of the industrial design process, the profession is ideally placed to pioneer a new discipline that is both industrial design and innovation.

3.2 *Industrial Design Defined*

The International Council of Societies of Industrial Design (ICSID) defines the nature of Industrial Design as follows:

Aim: Design is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanisation of technologies and the crucial factor of cultural and economic exchange.

Tasks: Design seeks to discover and assess structural, organisational, functional, expressive and economic relationships, with the task of:

- enhancing global sustainability and environmental protection (global ethics)
- giving benefits and freedom to the entire human community, individual and collective final users, producers and market protagonists (social ethics)
- supporting cultural diversity despite the globalisation of the world (cultural ethics)
- giving products, services and systems, those forms that are expressive of (semiology) and coherent with (aesthetics) their proper complexity

Design concerns products, services and systems conceived with tools, organisations and logic introduced by industrialisation, not just when produced by serial processes. The adjective 'industrial' when applied to design must be related to the term 'industry' or in its meaning of sector of production or in its ancient meaning of 'industrious activity'. Thus, design is an activity involving a wide spectrum of professions in which products, services, graphics, interiors and architecture all take part. Together, these activities should further enhance the value of life.

Therefore, the term 'designer' refers to an individual who practises an intellectual profession, and not simply a trade or a service for enterprise.

The last official working definition for industrial design adopted by ICSID was first drafted in 1969 by then ICSID Executive Board Member, Tomas Maldonado, and reads as follows:

"Industrial Design is a creative activity whose aim is to determine the formal qualities of objects produced in industry. These formal qualities are not only the external features but are principally those structural and functional relationships which convert a system to a coherent unity both from the point of view of the producer and the user. Industrial Design extends to embrace all the aspects of human environment, which are conditioned by industrial production." (www.icsid.org)

3.3 Industrial Design Practice

Industrial Design is the professional practice of creating and developing concepts and specifications that optimise the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer. Industrial designers develop these concepts and specifications through collection, analysis and synthesis of data guided by the special requirements of the client or manufacturer. They are trained to prepare clear and concise recommendations through drawings, models and verbal descriptions. Industrial design services are often provided within the context of cooperative working relationships with other members of a development group. Typical groups include management, marketing, engineering and manufacturing specialists. The industrial designer expresses concepts that embody all relevant design criteria determined by the group.

The industrial designer's unique contribution places emphasis on those aspects of the product or system that relate most directly to human characteristics, needs and interests. This contribution requires specialised understanding of visual, tactile, safety and convenience criteria, with concern for the user. Education and experience in anticipating psychological, physiological and sociological factors, (human factors), that influence and are perceived by the user are essential industrial design resources.

Industrial designers also maintain a practical concern for technical processes and requirements for manufacture, marketing opportunities and economic constraints, and distribution sales and servicing processes. They work to ensure that design recommendations use materials and technology effectively, and comply with all legal and regulatory requirements.

To this end industrial designers are called upon to explore the personal and corporate factors necessary for the commercial exploitation of new products, systems and services. In this context there exists a convergence between creativity, innovation and entrepreneurship. Here innovation is taken as "the successful exploitation of new ideas" (www.dti.gov.uk). Traditionally, UK design schools have excelled at producing highly creative visionary designers but they have been poor at producing designers able to exploit their creativity for entrepreneurial success.

3.3.1 Industrial Design Priorities

Before we get carried away with grand definitions of the profession and practice of industrial design we need to be reminded that industrial designers are primarily responsible for defining new products and user experiences. Understanding how people experience and use products, though complex is at the heart of the industrial design activity. Its complexity derives partly because each individual interprets and judges products differently and partly because of the sheer number of potential solutions to any given opportunity. Issues such as style and fashion act to influence peoples' views towards products. While some people may love a particular design, others may hate it. Contemporary society is becoming more diverse and demanding, and as such improving users experience with products is one of the many forces influencing manufacturers in their gaining of market share.

The industrial designer's goal is to satisfy consumer needs by integrating marketing, appearance, functional and engineering requirements into one product design solution (Tovey 1989). The importance of each of these requirements depends upon a 'hierarchy of consumer needs' (Jordan 2000), as shown in Figure 3.1, which suggests that once basic needs – such as functionality – have been met, consumers will look for something more. This hierarchy is based on a broader hierarchy of human needs described by Maslow (1970). In the first level of the hierarchy users expect products to perform an intended task or function, that is, products must be functional – note that here, the term ‘function’ refers to utilitarian functionality as one may argue that aesthetical aspects also accomplish certain type of functions. Once products are successful in function then users will demand products which are easy and comfortable to use, that is, users will desire usability. Once products are functional and usable, users will become more demanding and will want pleasurable products that provide emotional benefits. Innovation in the context of industrial design is therefore to be seen in both form and function.

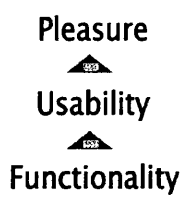


Figure 3.1 Hierarchy of consumer needs (Jordan 2000)

3.3.2 Innovation in Both Form and Function

When designing products, especially those to be launched in competitive markets, these three levels – functionality, usability and pleasure – must be satisfied. Norman, (2004) states that pleasurable products really do work better than those without this quality. An attractive product is unlikely to be successful if it is not functional, but a functional and usable product may also fail if its aesthetic or emotional values are incompatible with those of the consumer. Although functionality is, according to Maslow, in the lower level in the hierarchy of consumer needs, functionality is not always more significant than pleasure. As Luh (1994) points out, sometimes the aesthetic characteristics of a product may become even more important than its functionality.

Industrial designers create semiotic codes of reference which transfer certain emotions or values to the targeted consumers. The emotions elicited can make people feel happy or angry, proud or ashamed, secure or anxious (Jordan 2000). Consumers are willing to spend money on expensive products even though cheaper products may have similar effectiveness of use. As Norman (2004) claims, designers need to attend to a product's personality by designing all features of the product in accordance with the intended personality. For example, a product may exhibit any of a number of personalities such as playful, robust and sporty, and all aspects of the design including functional and aesthetic aspects will be used to communicate the intended personality to users. Given these intangible characteristics, industrial design can be seen as lying somewhere between the disciplines of engineering and art (Gotzsch 1999). While in engineering, the form of products is dominated by functional constraints, in art the form is emotional and influenced by aesthetic principles. Depending on the type of products, one discipline is more relevant than the other. In the case of furniture design, for instance, designers may move closer to art whereas in the case of designing a personal computer they may move towards engineering.

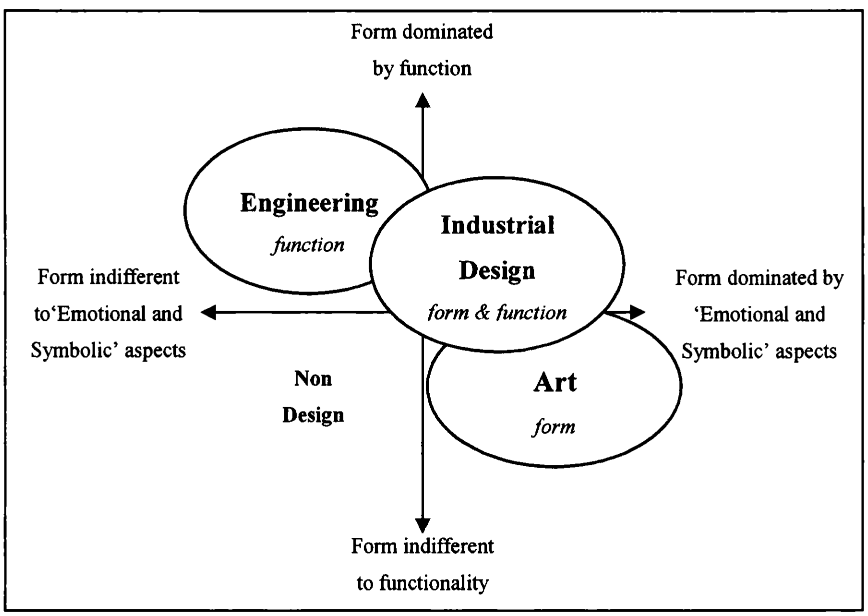


Figure 3.2 The Three Creation Processes and the Place of Industrial Design (Gotzsch, 1999)

Figure 3.2, based on Gotzsch positioning, illustrates the location of industrial design in between these two fields. The horizontal axis represents the degree to which the product's form is influenced by emotional and symbolic aspects, and the vertical axis the degree to which it is influenced by (utilitarian) function. Products situated on the bottom-left are considered non-designs because they do not have any functional and emotional and symbolic value. Gotzsch asserts that during the design process, industrial designers switch back and forth between functional aspects of design (related to engineering) and emotional aspects of design (related to art) depending on the type of product and stage of the design process. This suggests that designers are able to attend functional and emotional aspects of designs separately. In the context of this thesis the development of innovation can be seen as occurring in both aspects of industrial design, namely form and function. Striking the balance between form and function or the ID as art versus ID as innovation is a perennial challenge.

"... while both the Innovation crowd and the Gallery crowd have legitimate points-of-view, their effects on the overall perception of Industrial Design can be polarizing. We have to combine the two with lots of stuff in the middle. Industrial design may be seen as an idea engine, a utilitarian act of product development, or a prop in a story told by an author/maker. But it is also about the affordability and appropriateness of an object to an average person's life. And for more 'advanced' products, it can serve as a cultural interface, bridging and inspiring people to approach technology in far more than utilitarian ways. And it can be desirable, and pleasurable." (Amit 2007)

When discussing industrial design it is impossible to discuss innovation in one aspect without understanding its impact on the other. This is suggested by the statement "form follows function" made famous by the architect Louis Sullivan. Not wanting to examine this statement, because it is open to many interpretations (and independently of whether form follows or precedes function), it is apparent that the function of products depends on form. In other words, while form can stand alone without any particular function, the function of products only appears when it is expressed through form. Returning to Figure 3.2, if a designer develops a design by dealing only with functional aspects, it could be said that the product's form follows function. In contrast, if designers develop a design dealing only with emotional aspects, then the products function follows form. However, designers rarely focus only on one of these qualities, but form and function go hand in hand in the design process. This is suggested by the defined statement "form and function are one" made by the architect

Frank Lloyd Wright. The point that should be emphasised here is that the formal qualities of products are of equal importance to function and technology when considering the level of innovation in a product or system.

3.3.3 Sources of Innovative Opportunity

Innovation valued by the marketplace has long been recognised as a creator and sustainer of enterprise (Luecke 2003). An example of this can be seen in the business fortunes of Intel. Every time Intel's engineers produce a new generation of computer chips that its customers value, its fortunes are renewed. Immediate customers such as Dell, IBM, Toshiba, and other personal computer manufacturers quickly snap-up the new chip and so offer faster and more powerful machines to their customers who in turn apply the enhanced performance capabilities to a vast range of applications. But innovation can also destroy. In the early twentieth century economist Joseph Schumpeter (1934) described the economic, sociological and organisational impacts of innovation and its "winds of creative destruction". Those winds sweep away both old ways of doing things and the enterprises and institutions that cling to them. During the nineteenth century, innovations in mass production doomed local shoemakers, dressmakers, and many other artisans. That pattern is repeated today as superstores monopolise markets and decimate the ranks of small independent traders.

Opportunities for innovation can manifest themselves in seven distinct ways (Drucker 1985). Drucker's seven sources of innovative opportunity fall into two categories. The first four sources lie within the organisation, whether business or public-service institution, or within an industry or service sector. They are therefore visible primarily to people within that industry or service sector. They are basically symptoms. But they are highly reliable indicators of changes that have already happened or can be made to happen with little effort. These four source areas are:

- The unexpected – the unexpected success, failure, or outside event;
- The incongruity – between reality as it actually is and reality as it is assumed to be or as it ought to be;
- Innovation – based on process need;
- Changes in industry or market structure – that catch everyone unawares.

The second set of sources for innovative opportunity, a set of three, involves changes outside of the organisation or industry:

- Demographics (population changes)
- Changes in perception, mood and meaning
- New knowledge, both scientific and non-scientific

Drucker asserted that the lines between the seven source areas of innovative opportunities can be blurred and that there is considerable overlap between them. To respond to these opportunities the industrial designer needs to have an innovative environment comprised of individuals with an innovative mindset working within an innovative culture. When these conditions are met it enables the creative and innovational qualities of the industrial designer to find expression.

3.3.4 Innovation Process

Many managers, technical professionals, and scholars see innovation as a process. That process begins with two creative acts: idea generation and opportunity recognition. In the first, a person develops an insight about something new. Idea generation sometimes takes the form of a technical insight with no apparent commercial application. In most cases, however, a problem or an opportunity inspires the insight.

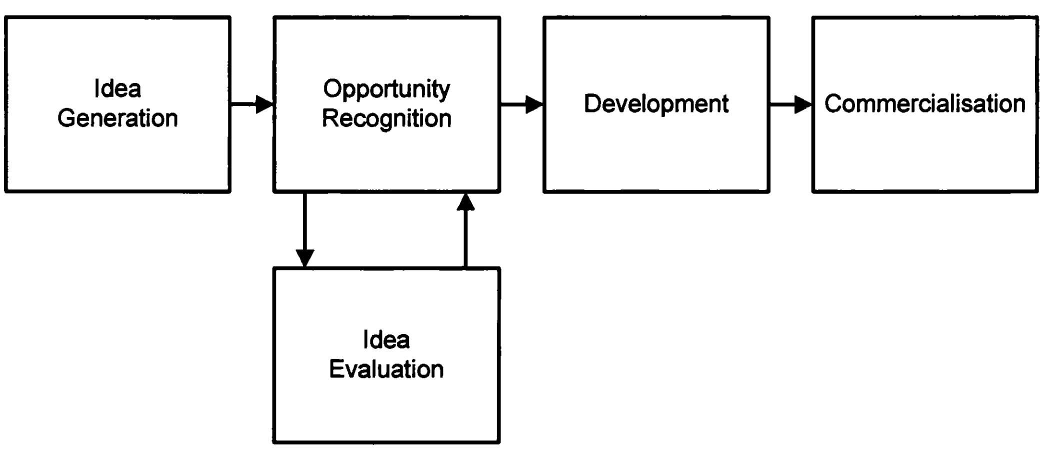


Figure 3.3 The Innovation Process (Luecke 2003)

As can be inferred from

Figure 3.3creativity and design play a critical role in the innovation process. Creativity sparks the initial idea; design helps to improve the idea as it moves through the various stages of the process. Indeed it is vital to note that much of what passes for ‘innovation thinking’ is actually solid design process in action. The overlap between the innovation and design processes is highly significant. As

Figure 3.4indicates:

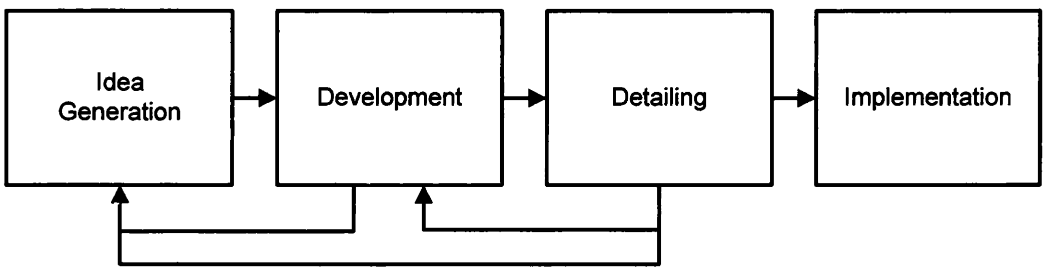


Figure 3.4 Typical Industrial Design Process (Author)

The parallels are clear and consequently demand further investigation if the relationship between industrial design and innovation is to be understood. One of the problems that innovators face in determining market needs is that target customers cannot always recognise or articulate their future needs. Because most are unaware of the technical or life-enhancing possibilities of breakthroughs in new technology or science, they tend to identify their needs in terms of current products and services with which they are already conversant. They express their needs in terms of incremental improvements to these products and services: a lighter lap-top, a smaller mobile phone, a lower carbon vehicle, bigger plasma television, etc.

To generate innovations that go beyond improvements to the familiar, one needs to identify and solve problems that the market may not yet recognise. This requires skills and knowledge that are found most completely in the industrial design arena. Industrial designers have long recognised the necessity for an observational approach to design. Using methods such as ‘ritual analysis’ and ‘empathetic design’ industrial design companies have developed entire design strategies based upon an anthropological approach. Such an approach precedes the drafting of the Product Design Specification (PDS) as the information gathered in the observational or empathetic stage contributes to the body of knowledge which supports the design innovation process. The knowledge and understanding developed in this pre-design stage informs the drafting of the PDS and provides an opportunity for first insight into the potential for innovation as it deals explicitly with the 'unit of adoption' described by Zaltman et al (1973) as discussed in Chapter 2. The PDS document is an essential tool in establishing the opportunities for innovation in that it lays down the goals both prescriptive and non-prescriptive for the project. The importance of a properly formulated PDS cannot be overstated. Too prescriptive, and it will inhibit innovation; too open, and it will result in a design which fails to address the core needs of the customer. Pugh (1999a) states:

"It is professionally impossible to give an opinion of any value about a design without knowing its origins – the PDS."

3.4 Industrial Design Process

3.4.1 Introduction

The theoretical underpinning having been established, and links to the innovation process outlined, it is now important to consider the practical processes which are undertaken by industrial designers in the execution of their profession. The process is essentially straight forward and uncomplicated. The complexity comes in defining where the role of the industrial designer ends and that of the engineer begins. In the same way one could just as easily ask the same question in relation to where the role of the artist, ergonomist, marketer, materials engineer, electronic engineer or entrepreneur begin and end. As Figure 3.2demonstrates, industrial design sits (often uneasily) between the traditional disciplines of engineering and art. Occupying this middle ground it has taken elements from both traditions and fused them to create its own unique approach. This fusion of elements is an important metaphor which underpins the various models of the industrial design process and even the very nature of creativity itself. Crosby (1968) stated that the creative process constituted a synthesis of ideas formed from pieces already in the mind by symbolic manipulation during dissociated thought i.e. at the subconscious level. It is this notion of dissociated thought and the extent to which it occurs in the subconscious that lies at the heart of many of the dissentions between the various models.

3.4.2 Design Process Modelling

Nystrom (1979) outlined the stages of Wallas' (1926) model of creative thinking and outlined the personal and cultural requirements required to facilitate each stage (Figure 3.5).

Stages	Requirements
Preparation	open to experience
	tolerance for ambiguity
	willingness to redefine concepts
	divergent thought processes
	intuitive ability
Incubation	(imagination)
	subconscious data processing
	independence
	psychological freedom
	psychological safety
Illumination	ability to switch from intuitive to analytical thought
	critical attitude
	convergent thought processes
Verification	analytical ability
	intelligence

Figure 3.5 Wallas' Model of Creative Thinking (Nystrom, 1979)

The internal dynamic tension within industrial design, which stems from the origins of the profession, can manifest itself most clearly in the approach to the design process. Essentially the three main schools of thought are the 'intuitive', 'systematic' and 'holistic' approaches. The intuitive approach emanates from a right hemispherical dominant mind and rejects any form of systematic design as being 'anti-creative' and too mechanistic. The systematic approach emanates from a left hemispherical dominant mind and rejects the intuitive approach as lacking rigour and scientific discipline. The reality is, however, that the optimum process lies between the two extremes in what one can call the 'holistic' approach. The holistic approach recognises the need for a marriage between intuitive and systematic design and recognises the strengths that each approach brings.

In Wallas' model (Figure 3.5) four distinct stages are identified – preparation, incubation, illumination and verification. In these stages one can identify both systematic and intuitive processes. At each stage Wallas identifies a series of characteristics or skills required of the designer. It is noticeable how this list relates to the various lists of innovative attributes considered in chapter 2. An examination of the stages reveals some interesting paradoxes in the design process.

During the preparation stage the individual designer develops, by observation and literature analysis, a detailed understanding of the project context and extent. This stage can assume a highly systematic form as the designer is concerned with establishing the exact facts and conditions which frame the project. At the incubation stage the designer is called upon to create concepts and synthesise a complex range of inputs in to the generation of potential solutions. Depending on the project, this stage can take on an entirely intuitive form with the designer relying on the subconscious as much as the conscious faculties to manipulate the information for a productive result. The illumination stage sees the ideas and concepts crystallise to give a meaningful result. Wallas argues that the designer comes to this result 'spontaneously' as a consequence of the subconscious manipulation and ordering of the previous stage. The final stage is one of verification where the concept which emerged during the illumination stage is tested and evaluated against the desired specification and in real world applications.

Despite concerns with Wallas' model, particularly the degree to which the incubation stage takes place in the subconscious, it continues to form the basis of many models in more recent times. Basadur et al (1982) suggest a three-stage problem-solving model comprising problem finding, problem solving and solution implementation. At each stage in this model a two-step process of ideation and evaluation occurs. Ideation refers to the intuitive uncritical generation of ideas and evaluation refers to the systematic application of judgement to select the best or most appropriate of those ideas. This model offers a distinction between 'behaviour' and 'thought processes'. Wallas' model was only concerned with identifying the thought processes.

This recognition that design is both thought and behaviour or theory and skill is important to absorb. It is interesting to note that historically two kinds of knowledge have been recognised – theoretical and technical. The word 'theory' derives from the Greek word "theoria" meaning: viewing, speculation, or contemplation. The notion of practical skill-driven knowledge is derived from the Greek word 'techne' meaning skill related to practical matters. These two kinds of knowledge coalesce in the design process, (Friedman, 1995). The International Design and Engineering Organisation (IDEO) have taken the principles underpinning Wallas' model and developed an iterative design process model. In their 2001 model, (Kelley and Littman 2004), they propose a five-stage process. Tom Kelley, IDEO Chief Executive, describes the five stages as:

- ***Understand*** *the market, the client, the technology and the perceived constraints on the problem. Later in a project, we often challenge those constraints, but it's important to understand current perceptions.*

- ***Observe*** *real people in real life situations to find out what makes them tick: what confuses them, what they like and what they hate, where they have latent needs not addressed by current products and services.*

- ***Visualise*** *new-to-the-world concepts and the customers who will use them. Some people think of this step as predicting the future, and it probably is the most brainstorming intensive phase of the process. Quite often the visualisation takes the form of a computer-based rendering or simulation, though IDEO also builds thousands of physical models and prototypes every year. For new product categories we sometimes visualise the customer experience by using composite characters and storyboard-illustrated scenarios. In some cases, we even make a video that portrays life with the future product before it really exists.*

- ***Evaluate and Refine*** *the prototypes in a series of quick iterations. We try not to get too attached to the first prototypes, because we know they'll change. No* *idea is so good that it can't be improved upon, and we plan on a series of improvements. We get input from our internal team, from the client team, from knowledgeable people not directly involved in the project, and from people who make up the target market. We watch for what works and what doesn't, what confuses people and what they seem to like and we incrementally improve the product in the next round.*

- ***Implement*** *the new concept for commercialisation. This phase is often the longest and most technically challenging in the development process, but I believe that IDEO's ability to successfully implement lends credibility to all the creative work that goes before.*

This can be visualised as a cyclic strategy (Jones 1992).

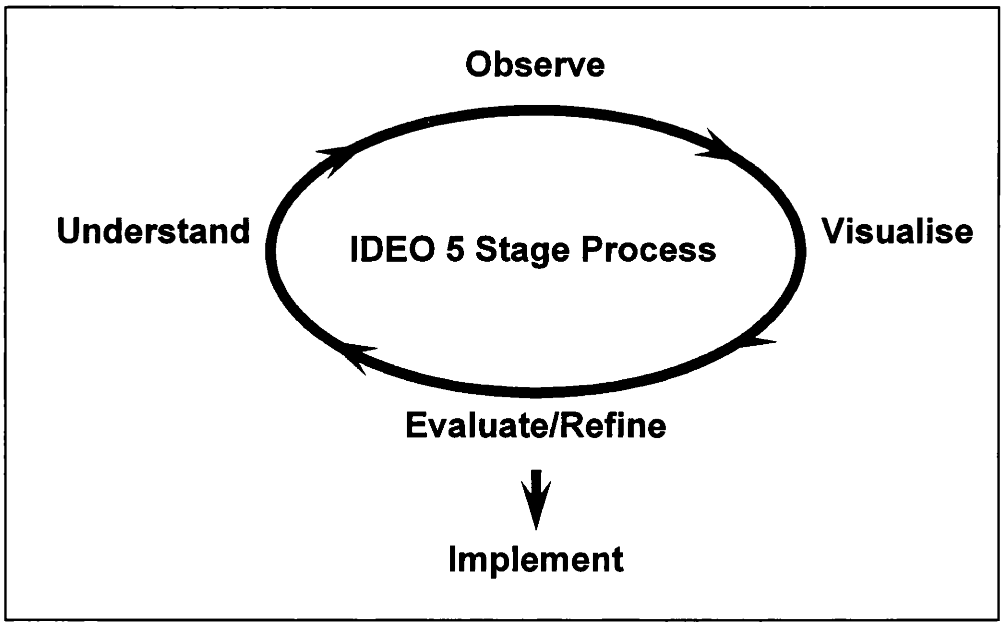


Figure 3.6 IDEO Five-stage Design Process Model

Central to each of the models discussed and as widely reported in the academic literature, the core of the design process is the generation of concepts. Concept generation provides the mechanism for innovation and the link to the wider innovation process.

3.4.3 Concept Generation

Investigations into design practice have motivated numerous researchers to define and specify patterns in the design process. These patterns, which assist in the development of design methodologies, suggest that the design process can be divided into various discrete stages with different tasks allocated to each one. Alexander (1964) claims that breaking down complex problems of design into smaller ones assists designers to tackle design problems in a logical way. Several authors have proposed different methods which divide the design process into stages. These methods are similar in that the phase where exploration of designs is performed with most intensity is located in the early stage of the process (Cross 1994). This can be translated into the search for innovation being most intense in the early stage of the design process. Models of the design process are normally illustrated using a flow diagram with a sequence of stages. The process starts with an initial need or motivation and ends with the production of a design package, such as drawings or construction plans. Every stage may be repeated several times and sometimes feedback loops between stages are necessary in order to continue the process. Figure 3.7 illustrates a model suggested by French (1985). The circles symbolise stages achieved and the rectangles represent different tasks.

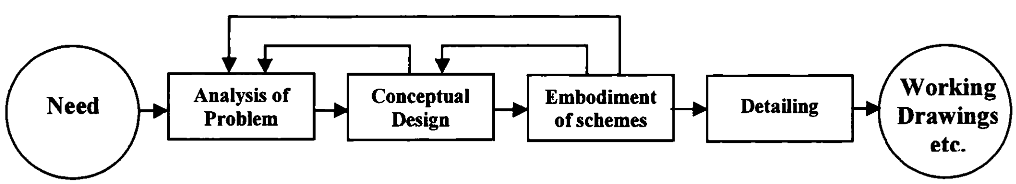


Figure 3.7 Model of the Design Process (French, 1985)

Pahl and Beitz (1984) outline a model of the design process that considers not only the sequence of stages, but also what the output of each stage should be. The first task of the design process is generally 'analysis of the problem', or clarification of the task. To realise the clarification a requirement list should be defined and include the inputs and outputs of the required function of the design. In order to analyse a problem it is often necessary to go one step forward and generate design solutions. This indicates that designers learn about the problem as they generate designs. Often, as Akin (2001) found, designers continue to explore alternative solutions through feedback loops even when they have already developed satisfactory design solutions. In the second stage, namely the 'conceptual design stage', designers generate broad solutions and, according to French (1985), it is at this point where many significant decisions are taken. This stage can be broken down into: (i) generate an idea; (ii) record the idea, e.g. through visual representations; and (iii) decide whether to continue to generate more ideas or explore the existing ones (Kolli et al 1993). The stage that follows conceptual design is the 'embodiment of schemes' where selected design solutions are developed in greater detail. French points out that in most cases there is a great deal of feedback from this stage to the conceptual design stage, often making the boundaries between both stages unclear. The last stage of the design process is the 'detailing stage' in which subtle, but no less important, formal features as well as colours and textures of the product are laid down.

As considered earlier, designing products often involves investigations into emotional aspects with the aim of fulfilling consumers' values. In some cases these aspects appear in the late stages of the design process, where emotional values – as well as other values related to pleasure – are integrated into the 'final' design in the form of features. There is significant scope for innovation to occur even at this late stage but it is at the conceptual design stage where the most promising innovations tend to emerge. The ideas at this stage are normally vague and therefore the design outputs, or concept designs, tend to be ambiguous, incomplete and without much detail. This is not to say that the small variations in form or function do not have an impact on the concept designs, in fact, small variations are often sufficient to change the essence of an idea and provide the innovation.

3.4.4 Divergent and Convergent Thinking

In order to conceive innovative solutions, designers normally generate a concept design first, and then explore the possibilities of that concept (Ward et al 1995). According to Guilford (1967), when generating concept designs, two types of thinking are used: divergent and convergent. Divergent thinking creates diversity in concept designs, which typically occurs in a spontaneous and random way. In contrast, convergent thinking displays a focus and is associated with evaluation and modification of one or few concept designs (Liu et al 2003). Cross (1994) contends that the design process contains irregular intervals of divergent thinking for the purpose of opening the search for new concepts, but in general, the process is convergent. Thus, the conceptual design stage is a generate-and-explore process in which most of the ideas are connected in some way. In a typical design project the initial search or exploration is conducted in a divergent manner. The designer initially entertains all avenues of creative research. Gradually as connections are made and some paths demonstrate more promise the field of investigation will converge and a proposal developed. As the diagram below indicates, the initial divergent phase of analysis and exploration (A) gives way to successive convergent phases of concept generation (B); embodiment or development (C); and detailing (D).

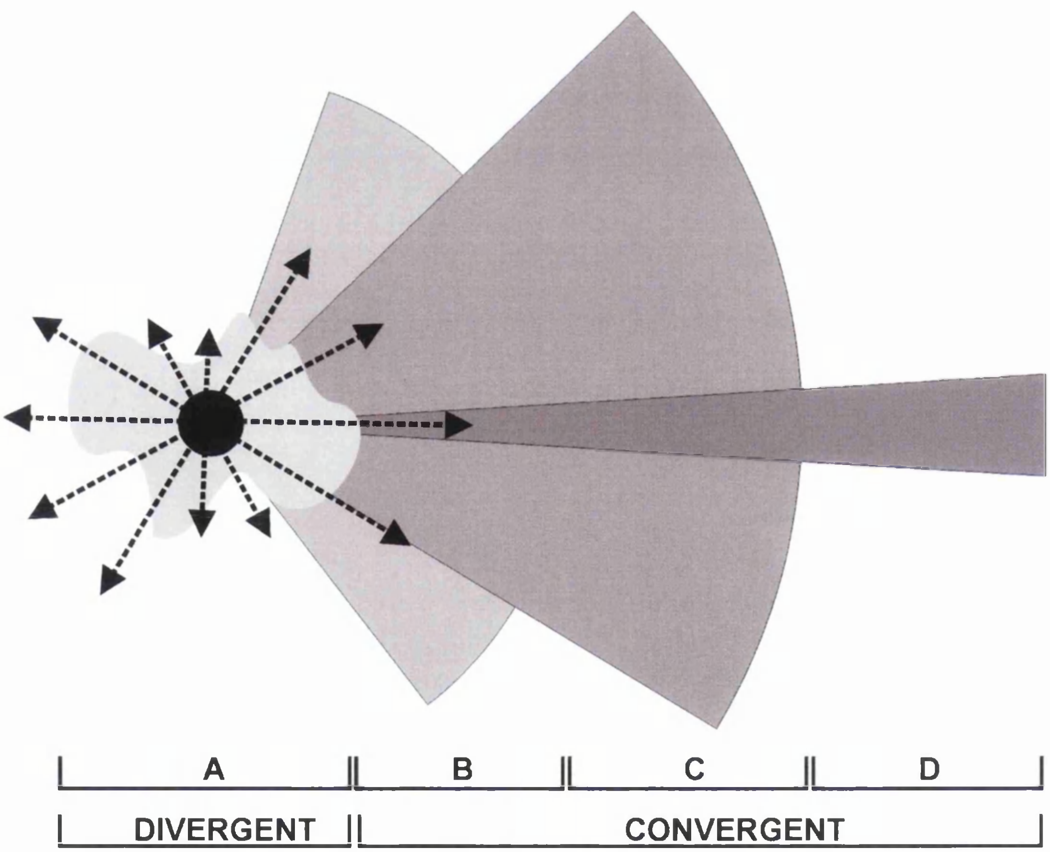


Figure 3.8 Divergent / Convergent Design Process Model (Author)

3.4.5 Creativity in Industrial Design

However, the generate-and-explore process itself is not sufficient to come up with innovative ideas. It needs creativity. As Boden (1995) notes, creativity is the ability to conceive or recognise novel (innovative) and valuable ideas. Creative designs provide feasible solutions to relevant problems in new ways. In addition, they grab a consumer's attention and make what Khaslavsky and Shedroff (1999) call 'emotional promises', which means that creative designs arouse an emotional link in consumers towards products. That is, creative designs are likely to satisfy emotional aspects. Studies of creativity in design have suggested that it is more likely to come up with creative solutions if several alternatives are explored (Cross 1997). Although many factors influence creativity, the processes involved in the manipulation of knowledge are the fundamental means by which people form creative ideas (Ward et al 1995). Several techniques have been developed with the aim to support creativity by assisting people to manipulate their knowledge. Brainstorming, for example, involves the manipulation of ideas based on different interpretations from people with different past experiences (Kelley 2001).

Creativity is often seen as a subjective and inaccessible phenomenon which partly depends on a designer's personal motivation and expertise. These methodical techniques seem to enhance a designer's creativity. A key strategy that designers may use to stimulate creativity is design precedents. Rarely are creative ideas initiated from scratch but they are a mixture of old and new ideas (Ward et al 1995). Contemporary architects, for example, sometimes base designs on precedent buildings designed by recognised architects (Goldschmidt 1998). Most engineering designs are adaptations or variations of existing designs, or creations of new designs on the pattern of previous designs (Eckert et al 2000). Design precedents are not only limited to man-made objects, products of nature (like the wings of dragonflies or raindrops) can also be considered as sources of inspiration or design precedents (Thallemer 2004). One way of stimulating creativity by recalling and processing design precedents is through vision, especially of form. Suwa (2005) demonstrates that expert designers are more skilled than novice designers in processing form from perception. In conceptual design both imagery and visual perception of form are often used simultaneously to explore new design alternatives. Although both mechanisms are similar (Kosslyn 1990) their consequences may be different. Kosslyn argues that one of the purposes of imagery is anticipating changes or transformations to physical objects. The work of Finke and Shepard (1986) suggests that there is a cognitive mechanism that integrates mental processes with the physical and graphic exploration of design conjecture. They suggest that designers use imagery to provoke and stimulate perception during design exploration.

While mental images allow design to be explored through the 'mind's eye', visual perception requires the support of visual stimulus. Purcell and Gero (1998) draw up significant implications that visual representations have during design and cognitive processes. They point out that visual representations, especially sketches, support cognitive processes – such as reinterpretation, emergence, and abstraction – that stimulate creativity. This emphasis on the importance of visual representations in stimulating the exploration of form and the development of novel ideas provides industrial design, with its combination of engineering and artistic approaches, with a pivotal position in the innovation process.

"Drawing is a means of education, of training hand and eye. It quickens the powers of perception and gives scope to the inventive faculties. It trains the eye to accuracy in observation and the mind to attention, comparison, reflection and judgment."

(Hammerton)

3.4.6 Technical Innovation in Industrial Design

Though central to the role of industrial design, a study of creativity and conceptual thinking does not tell the full story. Industrial design by definition is concerned with the formal qualities of products manufactured by industrial processes. As has been discussed this requires knowledge and skills in the interpretation of user needs and the generation of creative divergent concepts. What must also be recognised is the relationship between this conceptual more social science approach and the physical science approach necessary for the successful integration of form and function. This again introduces the notion of laterality, of left/right hemispherical dominance in the brain as discussed in 3.4.2. This integrated design approach or 'total design' (Pugh

1999b) requires the full integration of design, engineering and commercial activities to provide a systematic process for New Product Development). In Pugh's 'Total Design' model a central design core is encased by the related interdependent disciplines which are required to work together for successful product development and introduction.

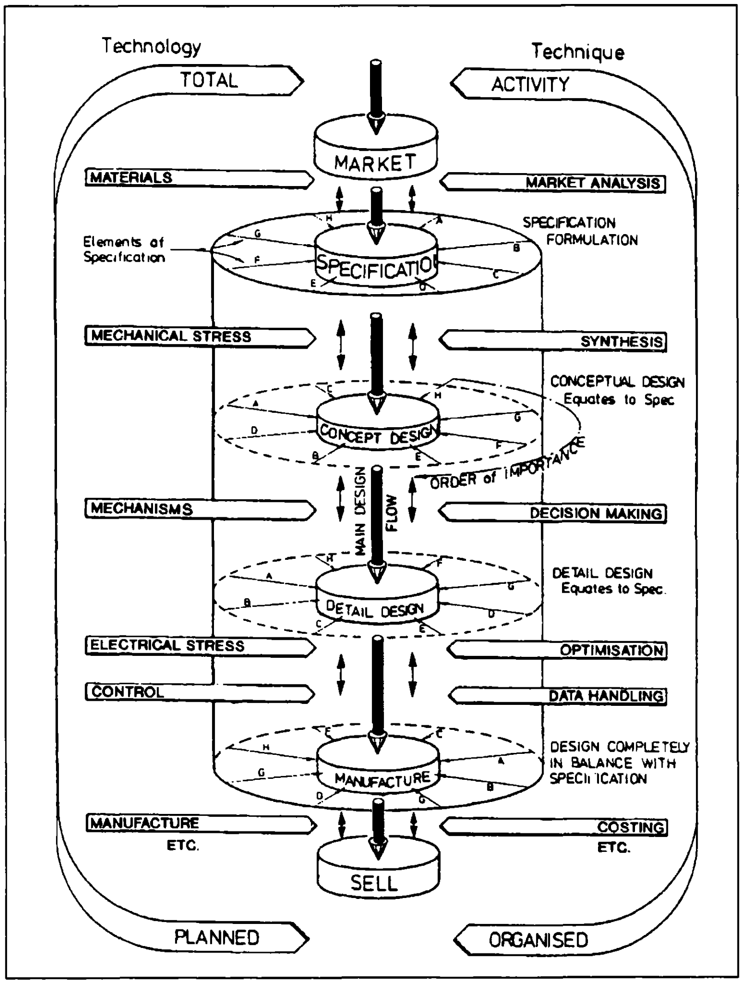


Figure 3.9 Pugh's Total Design Model

Clearly Pugh's model is more than another industrial design process model. Pugh calls for the total integration of the design, engineering and economic activities which coalesce in the development of innovative new products.

3.5 *Systematic Design Methods*

3.5.1 Introduction

Companies have never before faced the intensity of competition experienced in today's consumer product market. In the face of such competition, the ever more rapid emergence of innovations, changing consumer fashions and globalisation, manufacturers and producers are turning to systematic methods for the rapid generation of innovative design and are developing new design methods to keep their competitive edge and ensure their survival. Work on design methods has always tended to foster one or other dimension of the process, which isolates the notion of need from the industrialised product. An acceptable model of the design process, based on an analysis of several contacts with the academic and industrial world, must meet a large number of requirements (Nordlund 1996). To establish the optimum design method it is necessary to conduct a survey of existing design methods. A comparison of the various systematic methods presents clear evidence for the existence of a common underlying process which is contextualised in the specific application scenario for which the method was developed.

3.5.2 Summary of Design Methods

The methods compared were:

- Value Analysis (VA)
- QFD
- Axiomatic Design (AD)
- The Pahl & Beitz approach (PB)
- Concurrent Engineering (CE)
- Robust Design (RD)
- Design for Manufacturing (DFM)
- The TRIZ method

An analysis of the various design methods can present a confused picture of what each can offer the designer. Indeed, while they all advocate that they can act as a reference in terms of how a design project should be conducted, they rarely make reference as to what could be seen as complementary between them. This situation may lead to redundancy in terms of the answers they provide for the designer. If an abstract mode is adopted for the methods studied, the various representations of the development process provide us with a common vision which can be mapped against the four phases of Wallas' model:

- Preparation
- Incubation
- Illumination
- Verification

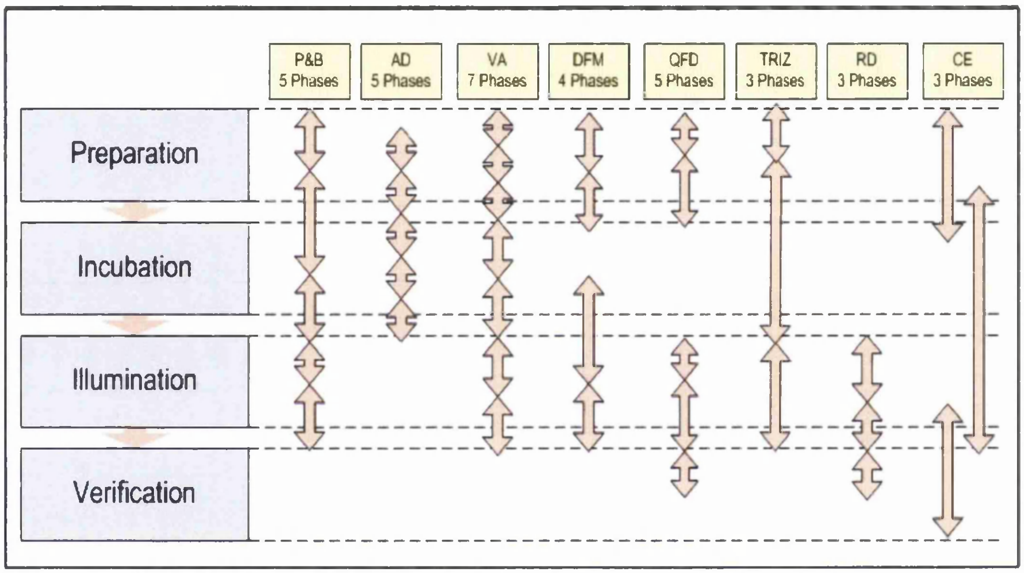


Figure 3.10 Mapping of Systematic Design Processes to Wallas' Model

The four phases clearly provide a frame of reference to map the essential features of each method considered. It is important to recognise that, though useful as a reference, it should not be seen as a rigid, fixed structure. This form of review has provided a useful vehicle for researchers seeking to identify the 'strong points' associated with a method and to link them up to one or more strong points in another. It should be remembered that no method takes the methodological history of the company or organisation into account. Their structure is fixed in relation to this, and any company that operates one method or another (or sometimes merely rules) is therefore obliged either to train themselves regarding the new method they wish to adopt, or to adapt it to what already exists in the company. For the purposes of this project the review serves to identify not only the range of methods to be taught to students of industrial design in the abstract but also what is the optimum methodology to develop the students' innovative abilities.

The designer should be able to increase the relevance of the application of the various design methods to his or her project with a minimum number of changes to his or her personal design process. In order to do this, the strong points of each method must be identified and integrated on an individual project basis so as to optimise the relevance of the method to the given scenario. Too often companies and organisations adopt a single method only to discover that it inhibits innovation and creativity rather than enhancing them.

The mapping exercise does highlight the atypical nature of one method compared to the others. TRIZ seems to offer a fundamentally different approach to other more well known methods. This is particularly evident in the creative or incubation phase. This has previously been identified in the literature (Souchkov 1997). Indeed the strength of TRIZ appears to be particularly evident in the inventive or creative phases. Comparing the various design methods reveals a certain amount of complementary features. Previous research (Malmqvist 1996; Schulz 1999; Cavallucci & Lutz 2000) supports the concept of taking the strong points from each and integrating them to create a bespoke methodology for each project. From the analysis it would seem logical that the ideal combination would consist of collecting and analysing data with QFD, generating concepts with TRIZ and ensuring the optimisation of parameters with Robust Design (Verduyn 1995). Yet this combination is only ideal from a theoretical point of view. A panoply of difficulties awaits designers who wish to combine these methods.

- Difficulties in skill-building for a set of methods which are not mastered
- Difficulties in combining methods in the same project or the need to create interfaces between them
- The time-span of the project is increased significantly due to the inertia inherent in applying multiple methods

To avoid these problems the key is not to integrate a method wholesale, but to integrate its strong points alone.

3.6 *Industrial Design as an Economic Priority*

3.6.1 Introduction

To effectively employ the range of skills required for the generation of innovation is challenging. In most business innovation models Industrial Design fails to get even a mention. Often when it does it is relegated to the supporting role of aesthetic design. However, in business sectors which are traditionally considered design intensive, industrial design has been given a greater role. In the furniture and lighting sector there is an established tradition of industrial design featuring at an early stage in the development process. It is increasingly recognised that Industrial Design, when integrated into the product development process impacts on company performance. Early involvement of industrial design in technology-driven sectors such as personal computing and home entertainment systems has been adopted by many large corporations such as Apple and Philips Electronics. Apple, for example, by introducing the ground-breaking iMac, not only boosted its market share and profits, but also started a trend toward style and fashion in personal computers (Reinhardt and Hamm 1999). Despite strong anecdotal evidence to support the positive economic benefits and impact on innovation outcomes of the early introduction of industrial design there is a scarcity of quality research to quantify its impact.

3.6.2 UK Design Survey

In the UK, industrial design has typically been seen as an adjunct to more traditional disciplines such as engineering and economics. Despite this perception deficit, industrial design continues to play a significant role in the economic health of the nation. In the manufacturing sector, industrial design is one of several key areas critical to new product development, together with research and development (R&D), marketing, manufacturing, and purchasing, among others. Industrial design contributes to new product development (NPD) by enhancing customer interface with the product, including ease of use, capabilities, and appearance. Over the past two decades, awareness of the role that industrial designers play in producing products has increased. Researchers in fields like marketing such as Dahl et al (1999) and Srinivasan et al (1997) have acknowledged the importance of the role that industrial designers play in producing products that are successful in the marketplace. However, quite often, industrial design is not distinguished from broad conceptions of design (inclusive of engineering design), and this has resulted in an incomplete understanding of the contributions made by industrial design and industrial designers.

The UK Design Council published a comprehensive survey of attitudes to design in 2006 (www.designcouncil.org.uk/factfinder). For the National Survey of Firms, published as Design in Britain, the survey team questioned 1,500 businesses with ten or more employees. From an initial telephone survey they identified 250 where the use of design had made a direct impact on a number of measures, such as competitiveness, market share, turnover and employment. This smaller group of 'design alert' firms were then subjected to more detailed questions on their use of design, and the financial and performance benefits they received from it. Amongst the findings of the survey were a number of headline facts about the role of design. Businesses where design is integral to operations are twice as likely to have developed new products and services. In the past three years, four fifths of them have, compared to a UK average of 40%. Rapidly growing businesses are nearly six times more likely than static ones to see design as integral. Increasingly the climate is changing and industrial design is now seen as an essential instrument of economic development in the manufacturing sector. Manufacturing is the sector most positive about design in the UK with 50% of manufacturers feeling design has either an integral or significant role to play in their business, compared to a UK average of 37%. 79% believe that design is integral to their future economic performance and 77% recognise the link between design and profitability.

3.6.3 Design Attitudes in Wales

In the specific regional context of Wales the 2006 survey paints a picture which is encouraging but confused. A third (32%) of Welsh businesses think design has a significant role to play in their business against a UK average of 22%. In the manufacturing sector the picture is disappointing with only 17% of Welsh businesses using product and industrial design in their business. This does, however, match the fact that only 13% of Welsh design businesses offer product and industrial design services. It is clear though from the evidence presented in the literature that industrial design is increasingly seen as a factor in innovation and business growth. This shift in emphasis is in line with current Welsh Assembly policy, which places an increased emphasis on innovation and enterprise.

In particular the Assembly's vision for Wales as expressed in the publications '**A Winning Wales - the National Economic Development Strategy of the Welsh Assembly Government'**, (WAG, 2001) and '**Wales for Innovation – the Welsh Assembly's Action Plan for Innovation**', (WAG, 2003)

In '**A Winning Wales**' the Assembly's vision is:

'To achieve a prosperous Welsh economy that is dynamic, inclusive and sustainable, based on successful, innovative businesses with highly skilled, well-motivated people.'

The report identified key actions for the development of a vibrant Welsh economy:
To encourage innovation:

- by ensuring that all businesses realise the potential of innovation in developing new products, processes and management practice, and maximising the use of information and communication technologies;
- by enabling strong links between businesses and our education institutions on a wide range of matters including recruitment, training, management development, international networking and technology transfer;
- by strengthening the technology base of our education institutions;
- by enabling the successful commercial exploitation of good new ideas from wherever they emerge;
- by testing our advice and support services for their capacity to promote innovation.

In the foreword to the Welsh Assembly's Action Plan for Innovation the Minister states:

"Innovation is at the heart of the Knowledge Economy, which is based on the successful exploitation of knowledge, ideas and creativity. 'A Winning Wales', the Assembly Government's economic development strategy, identified innovation as one of its crucial factors for transforming the economy of Wales into the "Dragon Economy". 'Wales for Innovation' now sets out how this vision for innovation is being developed; describes the funding, programmes and initiatives to facilitate increased innovation; and points to other strategies and action plans delivering key policies supportive of innovation."

This translates into five key strategic goals:

- Communicating what can be achieved through more innovation
- Developing more high growth potential businesses
- Better equipping people to innovate
- Simpler, more effective, business innovation support
- Maximising the economic development impact of our universities and colleges

It is clear from Welsh Assembly strategic documents that the development of innovative products is a key priority for the development of a dynamic economy. It is therefore vital that industrial design education responds to the challenge and ensures innovation is at the heart of the process. By understanding the characteristics of an innovative mind we can attempt to create an environment and engender a spirit whereby these characteristics are encouraged. By these means innovation is stimulated, not by artificial means or arbitrary targets but by an organic process of stimulation and incubation. By creating an organic pedagogy for the nurturing of innovative attributes we create a sustainable model.

A similar approach is being recommended by professional institutions, such as the Chartered Society of Designers, through their programmes of Continuing Professional Development (CPD).

3.6.4 Economic Benefits of Industrial Design Innovation

Research conducted in the Netherlands in 2000 (Gemser and Leenders 2001) sought to determine the true economic benefits of industrial design innovation to a business. They considered three factors based upon Walsh et al (1992):

- Industrial design intensity;
- Industrial design innovation strategy;
- Company performance.

Industrial Design Intensity

Here four indices were used:

- The percentage of NPD projects in which professional design expertise was used
- The number of design awards/prizes they had won
- The number of temporarily employed design apprentices and students from design institutions [item based on interviews]
- The average expenditure on product appearance during NPD projects
  (For all items, a time span of three years was used.)

Industrial Design Innovation Strategy

To determine the ID innovation strategy of the companies, respondents had to indicate whether, in the three years preceding the study, the designs created by their firm were in general similar to designs already put on the market by competitors or original in the sense of being truly different from designs developed at an earlier date by competitors. Companies whose designs were generally similar to those put on the market by others were considered to be pursuing a design imitation strategy; companies whose designs were generally original were seen to be pursuing a design innovation strategy.

Company Performance

To measure the business performance of a company, managers were asked to rate their firm's performance against competing firms. Specifically, managers were asked to score their firm's profit, profit growth, and turnover growth on a scale from 1 to 5, with '1' indicating that the firm belonged to the lowest-scoring 20% of competing firms and '5' indicating that the firm belonged to the highest-scoring 20% (Dess and Robinson 1984). In addition, the managers provided self-reported objective data on turnover (in the preceding three years), profits (in percentage of turnover), and export sales (in percentage of turnover).

Correlations between design intensity and business performance indicators—by industry

Variable	Furniture sample	Instruments sample
Profit-in % of turnover ('95)	.05	.50**
Profit	.02	.48**
Profit growth	.00	.30*
Turnover (averaged over '93-'95)	.16	.34*
Turnover growth	−.13	.15
Export-in % of turnover ('95)	−.12	.56***

* $p < .10$; ** $p < .05$; *** $p < .01$ (one-tailed test)

Figure 3.11 (Gemser and Leenders 2001)

The outcomes indicated a correlation between increased investment in industrial design and increased profitability. They also noted that this was greater in companies where the market differentiation based on technology had diminished and industrial design had enabled businesses to differentiate their products on form and interaction. They did not advocate delaying the introduction of industrial design to the mature stage of a technology as effective use of industrial design in the early stages allowed the business to establish brand identity and leadership.

A further study by Hertenstein et al (2005) set out to determine a causal relationship between industrial design innovation and corporate profitability. They concluded that proving "good design is good business" and that there is a causal relationship is an extremely difficult proposition. Their work built upon previous studies (e.g. Veryzer, 1993 and Gemser and Leenders, 2001).

They considered the following factors:

- Quality of the firm's design programme (e.g. number of design awards, peer recognition)
- Quality/excellence of design evidenced in the firm's products, collateral marketing materials, etc. (e.g. their opinion of the firm's design of products and materials)
- Importance placed on the firm's design programme (e.g. investment in design)

They concluded that establishing a causal linkage between industrial design and corporate performance was challenging in part because industrial design may be difficult to isolate from other participants in the new product development process. They recommended further investigation of the process by which 'good design' translates into improved company performance.

"The statistical tests in this study only can tell us what the outcome was; they cannot illuminate how it was achieved. Even so, understanding how good industrial design generates good financial performance is fundamental to measuring design's contribution and is key to improving the day-to-day work of industrial designers."
(Hertenstein et al, 2005)

It is clear that industrial design, if introduced at the earliest practicable point in the product development process, plays a significant role in company success and profitability.

But what of industrial design education? To what extent is innovation taught or even encouraged in higher education. The next chapter considers this question as it pertains to one such H.E. institution.

4 A Study of Innovation Pedagogy – Phase 0

"Design is a way to and from life. Like giving birth, it can be painful but it is also the greatest feeling making real ideas."

(Arik Levy, 2001)

4.1 Introduction

From the outset the goal of the Swansea study was to establish an environment within which both undergraduates and academics would be encouraged and given opportunity to innovate. It was essential therefore to understand the nature of innovation and in what forms it could be observed, analysed and nurtured. Chapters 2 and 3 provide an overview of innovation and industrial design and establish the context for the thesis. This chapter describes an indepth study of innovation pedagogy conducted during 1997 with the aim of creating a formal structure for teaching, learning and assessment which met the rigorous academic requirements of the University and Quality Assurance Agency (QAA), but which also provided scope for innovative experience and innovative outcomes.

From the review of the literature it is evident that, in order for innovation to flourish, it has to be supported or nurtured at the individual, organisational and cultural levels. Innovation does not 'just happen' – it requires a combination of conditions to bring about its occurrence. In formulating the resulting Swansea Industrial Design Innovation Model the author first engaged the support of the Faculty in conducting an extensive review and developing an initial strategy for encouraging innovation. Building upon the initial review the author, in conjunction with the programme team, undertook a three-phase programme development cycle with the aim of encouraging and nurturing an innovative mindset amongst undergraduate industrial designers. The three phases are summarised in Part B, chapters 4-7 with the outcomes analysed in Part C, chapters 8 and 9.

4.2 Background

The initial focus of the study was a review of the existing pedagogical model to identify strengths and weaknesses and develop strategies for a new model which could deliver the desired innovative outcomes. The primary vehicle for delivering industrial design education within the Faculty of Applied Design and Engineering was the BSc (Hons) Product Design. Originally validated in 1992 in a joint initiative between the Faculty of Art and Design and The Faculty of Electronic Engineering, the programme had by 1997 been running for five years. In 1997 the programme underwent a major quality review and a change of leadership. The review provided an opportunity for reflection and change. The BSc (Hons) Product Design programme was developed to conform to the Council for National Academic Awards CNAA guidelines and aimed to satisfy two very strong and competing demands. The programme was envisaged as a 'midi tech' programme positioned midway between electronic engineering and industrial design.

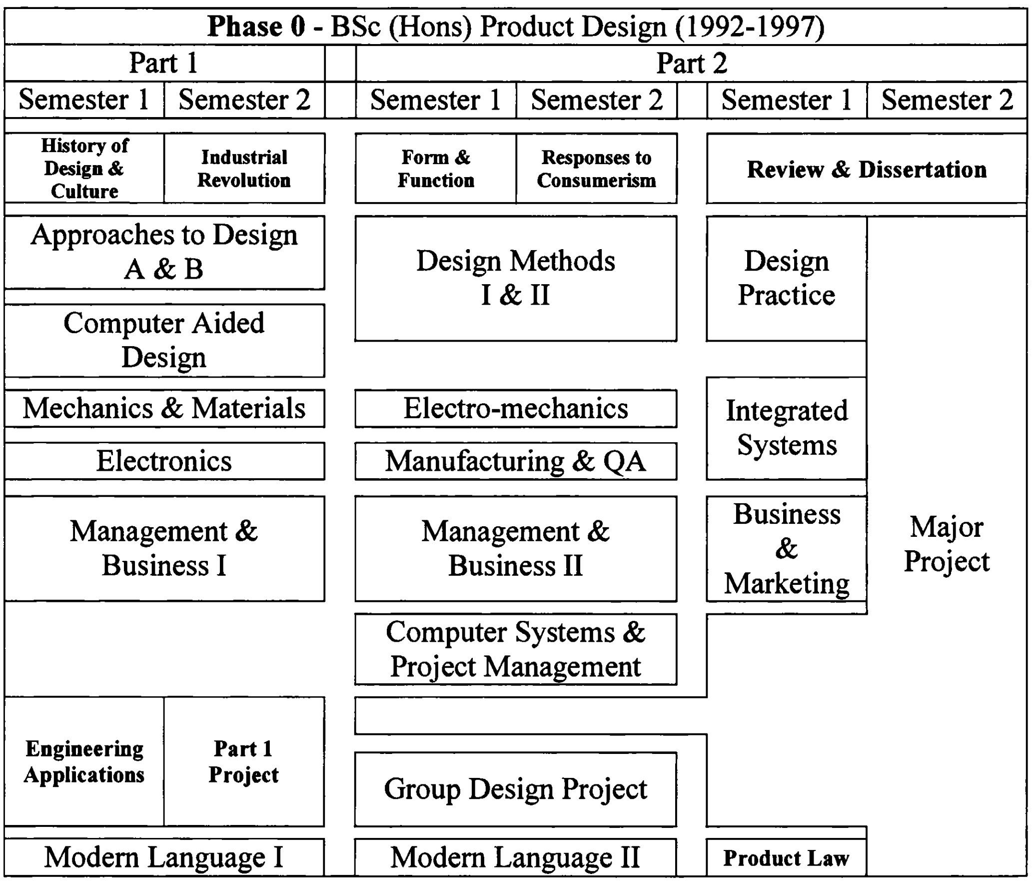
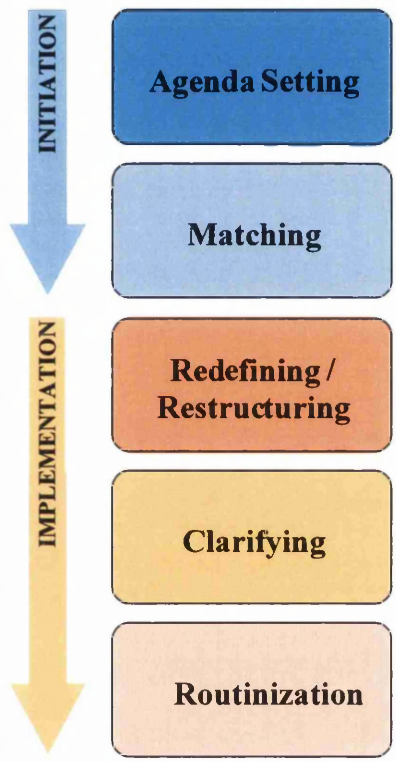


Figure 4.1 Original BSc (Hons) Product Design Structure (Eagle et al 1991)

It was the consensus that by 1997 the programme was unable to deliver either an adequate level of electronic engineering proficiency or an adequate level of industrial design outputs. Consequently the decision was taken to focus the programme on the acquisition and development of suitable industrial design knowledge and reduce the level of electronics delivered. Once this decision had been made it opened the door for a root and branch review of the programme to identify more appropriate strategies for the development of innovation through industrial design. The review team adopted the organisational model for innovation defined by Rogers (1983) discussed in Chapter 2. As the objective of the review was to identify the degree to which the study of industrial design could produce innovativeness and innovative outcomes it is appropriate that the review process itself be innovative. In following the five-stage process for organisational innovation identified by Rogers the team embarked on a focused and deliberate review of the teaching of industrial design methodology, the assessment of student outputs, the structure of the programme and the nature and quality of the learning environment.



Rogers' 5 Stage Model for Organisational Innovation

The review focused on three factors:

- Pedagogy
- Structure
- Environment

4.3 Review of Pedagogy

Pedagogy is a word which fills the heart of many creatives with dread. The word itself is innocuous enough meaning the principles, practice or profession of teaching. It is in the connotations those meanings implied that the problem lies. Images of a pedantic or dogmatic pedagogue, unyielding in the application or administration of a strict code or process cut across notions of creativity and innovation. Yet the business of a teaching university is that of pedagogy. In the context of this study that university is Swansea Institute and the pedagogy is that of the teaching of industrial design theory and practice. Much time is expended developing and maintaining systems of academic instruction. In the contemporary higher education system the degree of scrutiny is unparalleled. Programmes are evaluated and processes audited both internally and externally to ensure they meet the highest academic standards. The review of pedagogy required to initiate the study was therefore not unusual. The review of the pedagogical approach was divided into two distinct elements:

- Teaching, Learning and Assessment
- Communication

4.3.1 Review of Teaching, Learning and Assessment (TLA)

The original programme was devised as a means to integrate the acquisition of knowledge and skills in electronics and industrial design. The resulting TLA was dominated by traditional lectures, phase tests and closed-book written examinations. Teaching was primarily the responsibility of engineering lecturers with no industrial design experience. The approach was therefore designed to instil knowledge rather than to allow for the development of knowledge. The timetable was heavily weighted towards formal lectures with little time for reflection and student-centred learning. Assessment was primarily in the form of written examinations at the end of each 15-week teaching block or semester. Project work was conducted and studios were provided for the development of design skills but there was a lack of opportunity for tutor-supported reflective practice.

The TLA review addressed the programme delivery in terms of the five integrative themes which ran through the programme: Art and Cultural Context, Design, Technology, Management, Integrative and Supportive. The Art and Cultural Context theme focused on the socio-cultural context of design and allowed students to contextualise their work. This theme was seen to work well and students were able to address issues of historical and cultural relevancy in their design practice. The Design theme focused on the acquisition of theoretical and practical skills for the execution of design briefs. This theme included traditional studio and advanced CAD tools. The review found that, whilst there were opportunities for students to engage in a very active and progressive way in the design process, there was little opportunity for innovative thinking. The Technology theme was by far the dominant component of the programme. The six modules were delivered by over half the teaching team. The impact on the student experience was evident in an over emphasis on the technological content of products rather than a more open innovation led approach. The fragmentation in delivery also caused problems in communication. The Management theme was identified as remote and arbitrary. The TLA approach lacked any contextual relevance to the development of industrial design skills. The remoteness of the team and the lack of contextual relevance led directly to the disengagement of the students from the theme. The final theme reviewed is an eclectic mix of Project Modules, Modern Language and Product Law. The theme was forward looking and internationalist but created further pressures on the core design modules.

4.3.2 Review of Communication

Problems of communication were caused by the lack of a common ambition and focus. With a very broad programme comes the problem of a very broad team. There was little experience in the original team of product innovation. The majority of academics came from a traditional technology background. The nature of the work previously conducted within the department was at HNC/D level with little emphasis on experiential learning. Studio sessions were therefore primarily teaching sessions devoid of exploratory knowledge development. A further problem which exacerbated the communication difficulties was accommodation. Little interaction occurred between year groups or between academics and students out of timetabled sessions or between academics due to the distribution of accommodation.

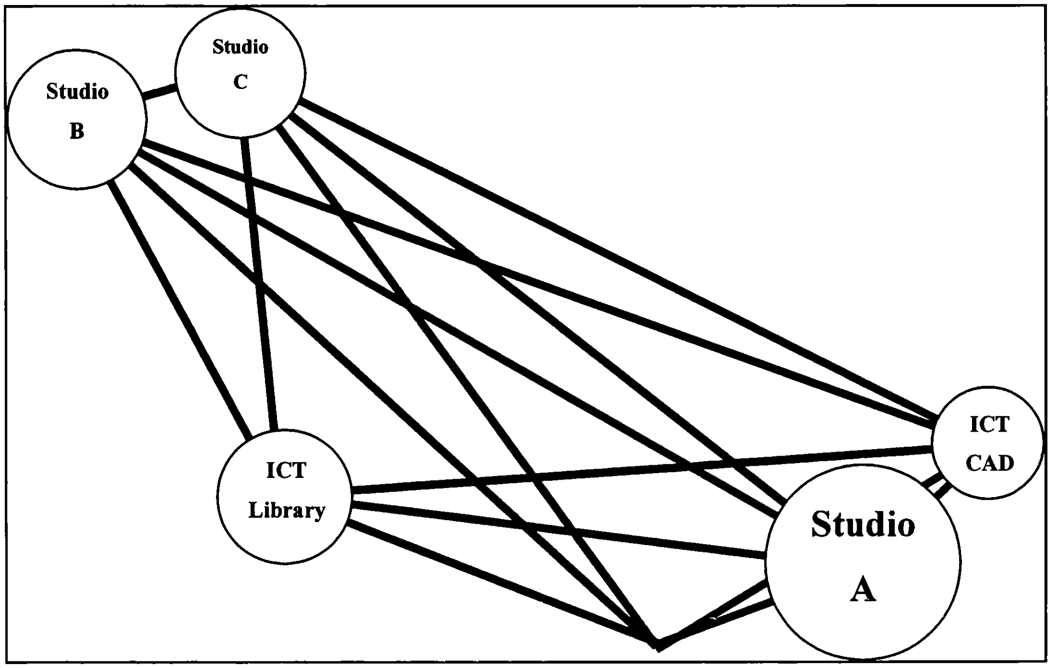


Figure 4.2 Pre-1997 Mapping of Student Activity and Resource Location

Student accommodation was split between two main centres on the Mount Pleasant Campus. This prevented the development of a studio culture and inhibited the academics' ability effectively to communicate with students collectively.

4.4 Review of Programme Structure

4.4.1 Module Review

Modular programmes of study can have a negative effect on innovation. Modularity creates discrete independent 'ghettos' of programme elements that cause the undergraduate to lose sight of the big picture. This was true in this case. There was too much fragmentation leading to over-assessment of secondary, supporting modules to the detriment of the core design and project work.

Figure 4.1 outlines the original modular structure. As can be seen, the structure was a combination of single and double semester modules or varying credit levels. The modules were developed with the aim of creating a programme to design the 'total product'. As such the content of the modules was comprehensive and all embracing. The modular structure was reviewed and each model analysed to determine its relevance and appropriateness. The following table was produced as part of the 1997 review.

BSc (Honours) Product Design Module Review Summary

Existing Module	Rationale for Change	Proposed Changes	New Module
Modules 1 & 6 • **History, Design and Cultural Studies** • **Industrial Revolution**	• As half modules they don't conform to the Institute's policy on modularity.	• Merge content. • Combine to create a single integrated module.	**PD101 Design Studies 1**
Module 2 • **Approaches to Design A & B**	• Currently a double module taught over two semesters. • Response to staff and student feedback. • Module needs to be more focused.	• Split into two distinct modules taught and assessed within the semester. • Two new modules in line with the Institute's policy on modularity.	• **PD104 Approaches to Design** • **PD109 Product Design 1**
Modules 3, 8, 13 &18 • **Mechanics and Materials** • **Electronics** • **Electro-mechanics** • **Manufacturing and QA**	• Currently taught as independent single modules taught over two semesters. • Modules don't conform to the Institute's policy on modularity. • Response to student feedback, reports from the external examiners. • To maintain the relevancy of the material to the student's future professional needs these modules needed to be integrated.	• Technology stream will be re-structured to create four new modules. • The material taught will be product centred, thus ensuring the relevancy of the subject to the professional requirements of the graduates.	• **PD105 Introduction to Product Technology** • **PD110 Product Technology 1** • **PD205 Product Technology 2** • **PD210 Product Technology 3**

• **Modules 4 & 19 Management and Business 1&2**	• Currently taught as independent single modules taught over two semesters. • Response to staff, student and external examiners' comments. • Modules need to be integrated into the core of the programme. • Modules need to be more focused on the business of design.	• Two new modules in line with the Institute's policy on modularity. • Some of the material originally taught within these modules will be moved and added to other modules to support the programme's aims and objectives.	• **PD106 Design Business 1** • **PD206 Design Business 2** Plus: Personal management • **PD 108 Design Practice 1** & Team management • **PD208 Group Design Practice**
Module 5 • **Engineering Applications**	• Faculty has expanded to include new areas of engineering. • The opportunity for the students to become involved with new materials and processes has expanded. • The re-structuring of the technology stream needs to be complemented with a hands-on experimental materials workshop. • To encourage students to explore new and more varied materials in their design proposals.	• Re-title the module to reflect the revised aims and objectives. • Some of the material originally taught within this module will be moved and added to other modules to support the programme's aims and objectives.	• **PD103 Materials & Process Workshop** Plus The electronics will be delivered in • **PD105 Introduction to Product Technology**

Module 7 • **Computer Aided Design**	• Modules don't conform to the Institute's policy on modularity. • Response to student, staff and external examiners' comments. • Market demands the teaching of CAD needs to expand from 1.5 modules to three modules value. • PC-based packages need to be introduced in the first year as a result of student feedback.	• Add a new first year, level one module to introduce the students to 2D and 3D PC packages. • Increase the teaching of 3D CAD in the context of product design.	• **PD102 Introduction to 2D &3D CAD** • **PD107 3D CAD 1** • **PD202 3D CAD 2** • **PD207 3D CAD 3**
Modules 11 & 16 • **Form & Function** • **Responses to Consumerism**	• As half modules they don't conform to the Institute's policy on modularity.	• Combine to create a single integrated module.	• **PD201, Design Studies 2**
Module 9 • **Part 1 Project**	• Response to student demand. • Module doesn't conform to the Institute's policy on modularity. • Need to increase the opportunity for integration of the modules within the semester.	• A new full project module which will include project management and planning.	• **PD108 Design Practice 1**

Modnles 10 & 20 • **Modern Language**	• Student response to these modules has been mixed. • The common cause of concern amongst the student body is that the time allowed in the existing programme structure is insufficient to develop a working knowledge of the language. • Students spend a disproportionate amount of their own time on this subject area, to the detriment of the core modules.	• The study of a modern language is to be made optional and not form part of the assessment programme.	• **None** (Students will be offered languages as an option only)
Modules 12 & 17 • **Design Methods 1 & 2**	• Module needs to be updated in line with changing industry needs.	• The module will be re-titled. • The delivery of the module will be modified to satisfy the Institute's policy on modularity. • There will me a strengthening of the modules with the inclusion of more design methodology and professional design practice.	• **PD204 Product Design 2** • **PD209 Product Design 3**
Module 14 • **Computer Systems & Project Management**	• Subject matter needs to be integrated into other modules. • Module comes too late in the course. • Strange mix of subjects.	• The material covered will be re-focused and divided amongst a number of new modules.	Computer systems • **PD102 Introduction to 2D & 3D CAD** Project management • **PD108 Design Practice 1**

Module 15 **Group Design Project**	• Module doesn't conform to the Institute's policy on modularity. • Feedback from students and staff indicates that the current structure and rationale is not fulfilling the course aims and objectives. • In response to an industry need for good team work and co-operation there is a need for a group design project.	• Project will be reduced to a single module taught in the second semester of year two. • Module will include team management and building exercises before the project commences. • The range of undergraduate disciplines involved will be reduced to ensure that the outcome of the project fulfils the programme aims and objectives. • New title to reinforce its role as an integrating design practice module. • A new module in the first semester will act as an individual project-based module to integrate modules taught in that semester.	• **PD203 Design Practice 2** • **PD208 Group Design Practice**
Module 21 • **Review & Dissertation**	• Module doesn't conform to the Institute's policy on modularity. • The length of the dissertation has been difficult to restrain, due to the amount of time students spend upon it. • Students wish to have more lectures and seminars to develop a deeper academic understanding of the issues relating to the philosophy of design.	• Teaching of contemporary design philosophy and ethics will be enhanced by the delivery of a new module. • The module will be more focused and the assessment criteria easier to implement. • The module will be a single module, in line with the policy on modularity.	• **PD301 Design Studies 3**

Module 22 **Design Practice**	• Module has developed into an important opportunity for the students to rehearse and refine their design skills before the major project. • In response to student, staff and external examiners' comments the module needs to be more focused on this role.	• The module will be re-titled. • Module will be focused to provide the students with the opportunity to produce a second, minor, project during the final year of the programme.	• **PD303 Minor Project** Plus Design practice • **PD209 Product Design 3**
Module 23 **Integrated Systems**	• Module has been well received by the students. • Staff and students suggest a need to focus the material on innovation in product technology. • Module doesn't conform to the Institute's policy on modularity.	• The module will be re-titled. • Module to focus on innovative products and technologies. • The module will be a single module, in line with the policy on modularity.	• **PD303 Emerging Prodnct Technologies**
Module 24 • **Business Policy and Marketing**	• This subject material is important to the development of a designer and will be retained. • Students, staff and external examiners feel the material needs to be in the first year of the programme.	• Module will be dropped and the material split between two other modules.	Marketing to be taught in • **PD106 Design Business 1** Business Planning will be integrated with the major project • **PD306 Major Project**

Module 25 • **Product Law**	• This vital subject area needs to be more closely linked to the individual's major project. • Module doesn't conform to the Institute's policy on modularity.	• The independent half module will be dropped and the material taught as part of the major project.	Product law • **PD306 Major Project**
Module 26 • **Major Project**	• In response to student, staff and external examiners' comments the project needs to be refined. • In order to make the major project a true showcase of the student's all-round design and academic ability the major project needs to be revised and re-focused.	• In response to staff experience and the comments of external examiners the major project will expand from five to seven modules value. • This will allow the key areas of business planning and product law to be incorporated. • The assessment of the project will be revised to ensure that all students are given specific interim and final deadlines to work to.	• **PD306 Major Project**

Figure 4.3 Review of Original Modules

The module-by-module review enabled the programme team to identify areas of the curriculum which required adjustment to increase the opportunities for innovation and enterprise.

4.4.2 Curriculum Review

In a modular programme of study the curriculum is divided into discrete units of study. In theory, this model produces flexible programmes of study which may be adapted to suit the individual student's aspirations. The reality is that modular programmes can and do fragment resulting in a failure to deliver on the overall programme aims and objectives. In the case of the BSc Product Design at the centre of this study, the failure was not related to the aims and objectives of the programme as given. Rather the failure was in the inability of the original programme to provide sufficient opportunities for innovation. The primary concern was the Major Project module in the final year. The original intent had been to facilitate the design and development of 'total product' solutions. The reality was over-assessment and lack of opportunity to experiment and advance innovative solutions. The associated modules in Product Law and Integrated Systems detracted from the project and resulted in students coming to the major project too late in the year. This limited the students' ability to explore alternatives and reflect upon the outcomes.

4.5 Review of Study Environment

As a relatively new area of study the industrial/product design programme occupied spaces which were dispersed across the campus. As a consequence, the programme lacked a home, an environment where the staff and students could work together. The phenomenon of the nomadic 'kit-bag' culture dominated, with students moving from building to building with no sense of belonging. The early years of the programme suffered from a lack of a dedicated design workshop resulting in students having to work from home or utilise inappropriate engineering workshops which lacked the necessary flexibility and technical support. The fragmentation in facilities highlighted in Figure 4.2 served to quench the innovative spirit of the students and staff. Whilst it is true to say that innovators can and do rise above adversity it is also true that, with such a degree of fragmentation and geographical dislocation, innovation is inhibited.

4.6 Analysis of Innovation Outcomes

4.6.1 Peer Recognition (Awards and Competitions)

The quality of design programmes is assessed in many ways. First and foremost the programme must comply with the requirements of the University and the Quality Assurance Agency. Secondly, from an academic perspective, there is the achievement of national and international peer recognition in the form of awards. Prior to 1997 the product (industrial) design programme at Swansea had won only one award. The 1997 Welsh Development Agency (WDA) sponsored Technology Award for Design and Product Engineering:

Shaun Miles	Winner of WDA Technology Prize: Design & Product Engineering	1997

This was regarded as a symptom of the problems affecting the structure and organisation of the programme and became a focus of the revised proposal developed for Phase 1.

4.6.2 Literature Based Innovation Survey

In the Oslo Report (1997) (2005) endorsed by the Organisation for Economic Co-operation and Development (OECD) Committee for Scientific and Technological Policy (CSTP), the OECD Committee on Statistics (CSTAT) and the Eurostat Working Party on Science, Technology and Innovation Statistics (WPSTI) a method for the collection of information about individual innovation cases reported in technical and trade journals is identified. The method is often referred to as the "Literature-Based Innovation Output Approach" (LBIO). Though the LBIO method lacks the conventional statistical frameworks used in innovation surveys (population, sample, etc.), it has the advantage that it is confined to product innovation data. In recent years, the method has been applied in Italy (Santarelli and Piergiovanni, 1996) and in the United Kingdom (Coombs et al, 1996).

The method requires the researcher to search through technical journals for instances of new products being introduced to the market. The rationale for the approach is based upon the premise that companies have an incentive to publicise their new products and services when they are adopted or introduced to the market. An important communication channel consists of press releases sent to trade and technical journals. When screening the trade journals, all new products or services mentioned in the editorial (often included in a separate 'new products' section) are taken.

The journals typically provide a brief description of the new product or service and the contact details of the organisation from which further information about the product can be obtained. Using this method a comprehensive collection of innovation cases can be built up, provided the journals selected are representative of the sectors screened. Selecting journals can be problematic.

4.6.3 Implementing an LBIO Study

The Oslo Manual recommends the following three-step procedure to ensure a reasonable coverage of sectors:

- Get the fullest possible overview of potentially relevant journals by search procedures in specialised libraries, and try to obtain sample copies;
- Contact the trade associations of all sectors to be covered and ask which journals they publish and whether they usually cover new products;
- Phone the public relations departments of firms in the relevant sectors and ask them to which journals they usually send press releases about innovation.

Recent LBIO studies have used the following dimensions to classify all new or changed products or services:

- The degree of complexity;
- The type of new or changed product or service;
- The properties of the new or changed product or service;
- The origin of the new or changed product or service.

Three degrees of complexity were distinguished:

a. High: the innovation is a system consisting of a larger number or parts and components, often coming from different disciplines (e.g. a weather satellite or an aeroplane);

b. Medium: the innovation is a unit consisting of a smaller number of parts and components (e.g. a laser printer, a textiles machine);

c. Low: a single innovation (e.g. an improved brake for a bike).

Five types of changes were considered:

a. A completely new or decisively changed product or service (e.g. a compact disk or electronic banking);

b. A new or improved accessory product or service (e.g. a safer child's seat on a bike or an improved life insurance connected to a mortgage);

c. A modestly improved product or service (e.g. a more energy-efficient machine or improved safety protection for credit cards);

d. A product or service differentiation (e.g. a soap with a different perfume);

e. A new or changed process.

All the properties which distinguish the new product from existing ones are included. The list may be lengthy, with some properties being named frequently: 'more user-friendly', 'safer, more reliable', 'more flexible', 'time-saving', 'more precise', 'longer life time', 'better for the environment'. Such information can be used to characterise the new or changed product more accurately, and for classification by type of change. For a distinction between a 'modestly improved' product (c) and a 'product differentiation' (d) the following rule can be applied: if at least one important property is mentioned in the journal, the product should be classified as a 'modest improvement' (c); if no property is mentioned, the product should be classified as product differentiation (d).

For the origin of the innovation, a distinction should be made between firms which have developed an innovation themselves and firms which are just selling somebody else's innovation. A typical example of the latter are export/import firms which act only as a distribution channel for innovations developed abroad.

4.6.4 Strengths and Weaknesses of the LBIO Method

The statistical properties of an LBIO database may appear questionable since standard statistical sampling procedures are difficult to apply. As a consequence of the method, the number of innovations identified and the degree of innovativeness presented is constrained by the number of journals reviewed. However, as the method addresses the innovations directly it provides a more tangible evaluation of the innovation than comparable indicators such as R&D expenditure or patents. The LBIO method results in a direct measure of innovation. It is a major advantage that it can, in theory, identify innovations in all sectors of the economy, including services and agriculture. The LBIO method is particularly interesting in that it can cover innovations in very small firms. Small enterprises are usually neglected in traditional surveys, due to cut-off (e.g. less than ten workers). Coverage of micro-firms or even lone innovators is important, since they make up a considerable share of innovations announced in journals (Kleinknecht and Bain, 1993). Moreover, there is still very little systematic knowledge about the innovation behaviour of micro-firms. Overall the results suggest that the LBIO data are fairly consistent with those from more traditional innovation surveys (Brouwer and Kleinknecht, 1996).

For a survey of student innovation, which by definition has not reached the market and which is not the result of significant expenditure of R&D investment, a form of LBIO offers a valuable method of measurement.

4.6.5 Implementing a Modified LBIO Survey of Student Innovation

The evaluation of innovation in an academic setting is problematic given that the specific novelty or innovative properties often lie outside of the assessment matrix for the module or programme concerned. The academic imperative can often be in conflict with the relative innovation of the product or service proposal presented. There is the problem of retrospectively identifying innovativeness in projects executed ten or more years ago in a consistent and unbiased manner. To facilitate the evaluation a modified LBIO method was adopted. Rather than trawling through journals to identify innovative products, a review of project reports between 1995 and 2007 was conducted. The review was carried out by a team of experienced academics with extensive experience of innovation in the context of industrial design. A five-point innovation evaluation scale was developed from the LBIO method described in 4.6.3. The scale was based upon the five types of change identified in the Oslo Manual.

Five types of changes were considered and a rationalised form used in the evaluation of the project reports:

a. Maximum Innovation – a completely new or decisively changed product or service;
b. Intermediate innovation – a new or improved accessory product or service;
c. Minimum Innovation – a modestly improved product or service;
d. Change without novelty – a product or service differentiation;
e. No significant change – a new or changed process.

The School of Industrial Design at Swansea Institute has maintained an archive of every major project and marketing report for the industrial and automotive design programmes. The archive includes the reports produced to support the major project of every successful graduate designer dating back to 1995. The reports were evaluated, without recourse to the original marks, to assess their innovation based upon an object approach derived from 1997 Oslo Manual. To minimise bias in the study the reports were anonymised and randomised to remove any correlation between the order of the evaluations and the phases of programme development they represent. In determining the level of measurement three types of data scales may be considered:

Nominal Scale – The simplest level of measurement where the function of numbers serves as a labelling system with no implication that one is better or greater than another;

Ordinal Scale – This is the ordering of categories with respect to the degree to which they possess a particular characteristic, without being able to say exactly how much of the characteristic they possess;

Interval Scale – These scales not only rank the objects with respect to the degree with which they possess a certain characteristic, but also indicate the exact distances between them.

Selecting the appropriate scale to adopt requires knowledge of the questions to be asked of the data in subsequent analysis. The scales are cumulative, i.e. the ordinal scale possesses all the properties of the nominal scale plus ordinality. An interval scale has all the properties of a nominal and ordinal scale plus a unit of measurement. As discussed in above five levels of innovation were identified as the basis for assessment. It was established in chapter 2 that innovation may be defined as "any idea, practice, or material artefact perceived to be new by the relevant unit of adoption" (Zaltman et al 1973). In Zaltman's definition we see the emergence of relativism in the discussion of innovation. The measurement of innovation may be either quantitative or qualitative. Thus innovation may be defined or evaluated using a semantic or qualitative approach. Semantic scales such as the Likert or Semantic Differential scales, (Likert 1932), offer a useful methodology for the construction of a metric to measure attitudes to, or perception of, innovation.

4.6.6 Likert Analysis

The exercise of a Likert scale allows for quantitative comparisons between qualitative responses. As identified by Likert (1932) participants in any survey of opinion employing this method must be given a choice measured on a known scale. Given that individuals are able to differentiate between an infinite number of choices on a continuous scale there remains debate amongst psychologists as to the optimum Likert scale to adopt. Use of coarse scales can lead to participants rounding up or down to the adjacent options. Too fine a scale may result in a loss of differentiation between options. Research by Munchi (1990) suggests that a seven-point Likert scale would produce a lower measurement error. However, given that the subject of the study was the level of innovation expressed in projects conducted in an academic institution, a scale correlating to a typical academic assessment scale was adopted.
A Literature-Based Innovation Output (LBIO) Analysis using five point Likert scale was developed based upon the categories identified by the Organisation for Economic Co-operation and Development (OECD), (OECD 1997). As the subject under consideration is potential innovation developed under academic conditions we must

assume that the intervals representing each response are not equally spaced and the data collected is ordinal as opposed to interval or nominal.

Object Approach – Degree of Novelty of the Product or Process Innovation				
No Significant Change	Change Without Novelty	Minimum Innovation	Intermediate Innovation	Maximum Innovation
1	**2**	**3**	**4**	**5**
Derived from: OECD-EUROSTAT (1997). The Measurement of Scientific and Technological Activities. Proposed Guidelines for Collecting and Interpreting Technological Data. Paris: OECD.				

Figure 4.4 Likert Scale developed for the modified LBIO study (chapters 4 to 7)

All projects completed prior to 1997 were evaluated by a team of experienced academics in the field of industrial design and innovation. The results were collated (Appendix 1, p264) and summarised in the following table and histogram.

Phase 0				
Level 1	Level 2	Level 3	Level 4	Level 5
26	16	6	3	0
Phase 0				
Level 1	Level 2	Level 3	Level 4	Level 5
50.98%	31.37%	11.76%	5.88%	0.00%

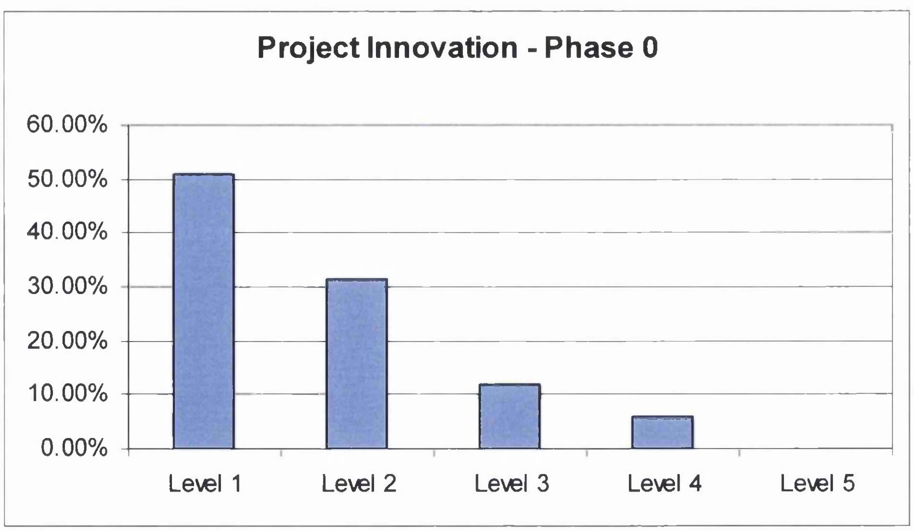


Figure 4.5 Innovation against the Likert Scale 1995-97 (Phase 0)

4.6.7 Altshuller Analysis

A second measurement scale was adopted by the team as an indicator of product innovation. Applying the same LBIO methodology described above, each project was reviewed against the innovation scale developed by Genrich Altshuller (Altshuller 1988). Originally developed in the 1950s, TRIZ (The Theory of Inventive Problem Solving) is based on studying and analysing patents in different technological fields. Altshuller himself studied more than 400,000 patents worldwide. To date, TRIZ specialists have analysed approximately two million patents. The analysis of these innovations revealed that not every invention is equal in its inventive value. Altshuller proposed five levels of innovation and determined the relative frequencies of patents falling under each level at his time:

Level 1: A simple improvement of a system. Requires knowledge available within a trade relevant to the system (32%).
Level 2: An invention that includes the resolution of a technical contradiction. Requires knowledge from different areas within an industry relevant to the system (45%).
Level 3: An invention containing a resolution of physical contradiction. Requires knowledge from other industries (18%).
Level 4: A new technology is developed containing a breakthrough solution that requires knowledge from different fields of science (4%).
Level 5: Discovery of new phenomena (1%).

Altshuller's Five Levels of Innovation				
Not Innovation	Innovation			
A Simple Improvement of a System	Resolution of a Technical Contradiction	Resolution of a Physical Contradiction	New Technology is Developed	Discovery of New Phenomena
1	**2**	**3**	**4**	**5**
Derived from: Altshuller, G. Williams, A. (1988), Creativity as an Exact Science, Gordon & Breach, New York.				

Figure 4.6 Altshuller's Five Levels of Innovation

The major project was chosen as the only means by which the effect of the entire programme of study had impacted on the student's capacity for innovation. Consensus evaluation of each project was undertaken by the author and two senior colleagues within the School of Industrial Design. The results were analysed to identify trends in the innovation outputs which could be used to develop the pedagogical model. The following table and histogram (Figure 4.7) indicates the innovation levels during Phase 0.

Altshuler's Five Levels of Innovation – Phase 0				
Level 1	Level 2	Level 3	Level 4	Level 5
32	14	5	0	0
Phase 0				
Level 1	Level 2	Level 3	Level 4	Level 5
62.75%	27.45%	9.80%	0.0%	0.0%

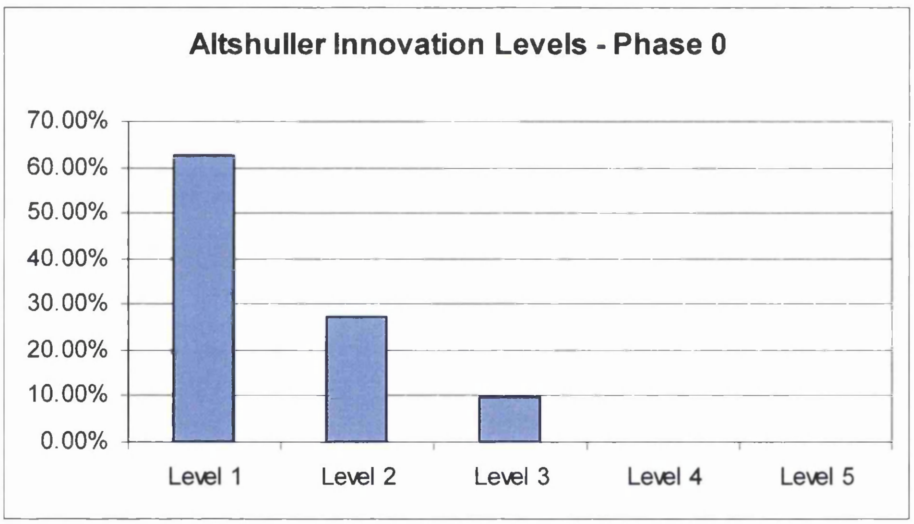


Figure 4.7 Innovation against the Altshuller Scale 1995-97 (Phase 0)

The Altshuller levels of innovation were based upon a survey of patents and as such were truly an evaluation of inventiveness rather than innovativeness.

The review of projects against two scales provided qualitative evidence of the levels of innovation present. The benchmarking of projects against the Altshuller scale produced a highly skewed distribution. The distribution is close to a classic J-shaped curve where values taper off very quickly. The Likert analysis produced a broader spread of values but still conformed to a classic J-shaped curve. What emerged from the review of projects in Phase 0 was the low level of innovation exhibited. The review highlighted the need to implement a revised pedagogy for the development of innovativeness in industrial design.

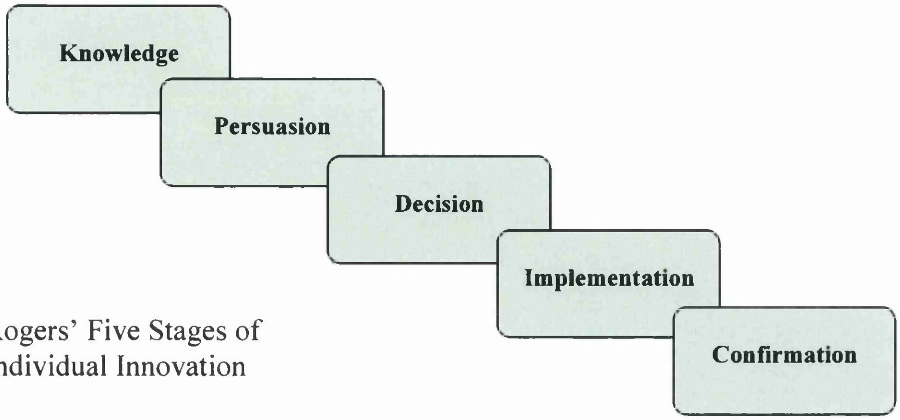
4.7 Development of a Revised Pedagogy

From the literature it is evident that there are a number of significant factors which inhibit or support the development of an innovationist culture.

Figure 4.8 lists key factors identified in the literature which support innovation from an individual, organisational and cultural perspective.

King (1987)	Farr and Ford (1990)	Gilbert & Freeman (1995)
Organisational	**Individual**	**Cultural**
• Organisational structure; • Organisational strategy, culture and climate; • Organisational size; • Organisational resources; • Organisational knowledge of innovations.	• Individual's perception about the need for change; • Belief that change can be achieved within the work role; • Belief that a successful outcome will emerge; • The individual's capacity to generate new and useful ideas.	• Develop an acceptance of change; • Encourage new ideas; • Permit more interaction; • Tolerate failure; • Provide clear objectives and freedom to achieve them; • Offer recognition.

Figure 4.8 Comparison of factors which support innovation



Rogers' Five Stages of
Individual Innovation

The issues addressed by these factors were considered in the review of the Major Project Pedagogy and applied to the revised TLA strategy. As discussed in chapter 2, Rogers (1983) identified five stages to individual level innovation.
The derived model served as a template for developing an innovation-friendly structure for the Major Project.

Knowledge Stage

A TLA strategy was developed to encourage the students to ask more questions. Only by asking the right questions can the individual identify the need or opportunity for innovation. Knowledge of an innovation is broken down into three distinct areas or domains.

- Awareness knowledge
- How-to knowledge
- Principles knowledge

If undergraduates are to become successful innovators or 'change agents' they need to understand the three domains of knowledge governing the innovation if they are to facilitate change or bring about a new innovation.

Persuasion Stage

As Rogers identified, this stage is knowledge dependent and results in behavioural change. The Major Project was re-structured to build in a stage whereby the student, using persuasion, communicates evidence, arguments and a rationale advocating acceptance of an innovative idea and participation in an innovation. This presentation stage causes the student to examine his or her proposal and identify its novel value.

Decision Stage

The revised TLA allows for greater accountability and autonomy by the student within an expanded Major Project. The decision stage is typically predicated on the basis of a trial or evaluation of the innovation by the student.

Implementation Stage

By extending the Major Project from 60 to 84 credits the team provided students with the opportunity to take their projects beyond the invention. Implementation is the reduction to practice of the inventive concept. As Rogers identified, without implementation innovation cannot be said to have occurred. The implementation stage becomes critical in the chain of events which comprise the individual major project.

Confirmation Stage

Post-adoption confirmation is the fifth and final stage of Rogers' innovation model, seeking reinforcement for the decision process already made by reviewing the implementation through feedback mechanisms. In an undergraduate project the key element to this stage is the reporting. The report in this case is in two parts: a technical evaluation report and a marketing report. The dual reporting strategy allows the student to evaluate both the technical execution of the project and the potential for reduction to practice of the final proposal.

4.7.1 Revised Modular Structure

The modular structure was revised. A number of supporting, non-core modules were withdrawn and replaced with additional design modules that utilised new technology in their delivery. The third year was completely re-designed. The previous collection of half modules, single modules and double modules was replaced by two new research-based modules, a conceptual minor project module and by a seven-module, 84-credit, major project. The concept behind the new expanded project was to integrate a number of valuable but discrete units seamlessly into one unified project.

4.7.2 Teaching Innovation

Team supervision of the major project underpinned by a system of pastoral tutors allowed the individual student to seek out the specific support he/she required. Each project attracted a unique team of supervisors. This removed any prospect of personality clashes or academic prejudice inhibiting the development of the project. The new research-based modules in the final year involve a team of staff delivering a rolling programme of lectures that the undergraduates take as a basis for further research. The outcome is a paper written within tight academic guidelines and presented in a conference format. The benefits of these modules is in the raised prominence given to research and in the greater value that each student attributes to his/her personal intellectual property.

Industrial Involvement

The model for industrial involvement chosen was that of student mentor. 'Memoranda of Understanding' were signed with three companies who provided information and advice to undergraduates at the research or practice level directly supported the development of innovation. The success of this involvement has been profound and has led to valuable contributions from the industrial partners on matters as diverse as Intellectual Property Rights (IPR) to suggestions for material and process selection.

4.8 Summary of Phase 0 Outcomes

The object of this phase was the review of an industrial design programme to determine how well it enabled the development of innovativeness in the student body. The outcomes of that review were embedded in a revised programme document produced in June 1997. The review concluded that five actions be implemented to improve the opportunity for innovation.

- Reorganisation of the modular structure and TLA strategy
- Removal of programme elements that didn't contribute to the development of innovation design skills and knowledge
- Reorganisation of the teaching and learning environment
- Increased studio-based studies and activities
- Restructuring of the Major Project module to include an innovation-centred approach to teaching, learning and assessment

These five actions were implemented from the beginning of the 1997/98 academic year. Chapter 5 describes the implementation of the actions and evaluates the outcomes.

5 Development of Innovation Pedagogy Phase 1 (1997-2000)

"The less you see the designer's effort in the work, the better – effort should not be a visual commodity; it's simply a means to an end."

(Sam Hecht, 2001)

5.1 Introduction

Following on from the 1997 review it was clear that the primary need was the creation of an innovative environment as highlighted by King (1987). The development of this environment drew heavily on the literature (Chapter 2); the experience of the programme team; and external examiners. The review identified five actions for implementation of change:

- Reorganisation of the modular structure and TLA strategy
- Removal of programme elements that didn't contribute to the development of innovation design skills and knowledge
- Reorganisation of the teaching and learning environment
- Increased studio-based studies and activities
- Restructuring of the Major Project module to include an innovation-centred approach to teaching, learning and assessment

5.2 Implementation of New Pedagogy for Innovation

5.2.1 Revised Teaching, Learning and Assessment Strategy

As discussed in chapter 2, a wide range of factors has been associated with innovation processes in organisations (for example, King 1987, Gilbert & Freeman, 1995). In developing a new Teaching, Learning and Assessment (TLA) strategy for encouraging innovation at undergraduate level these and others were referred to and employed to guide the development of content and process. In this phase, three particularly relevant issues were addressed: complexity, involvement and personal salience.

a. Complexity

As Bohlen has noted: "Other factors equated, the more complex an idea is, the more slowly it tends to be adopted" (1971, p. 807). The greater the complexity related to adopting an innovation or in merely understanding the innovation cognitively, the greater the resistance to an innovation (Perry & Kraemer, 1978). In this context the innovation is innovation itself, i.e. the innovation is the requirement for students to act in an innovative manner and for academics to support the innovation. The resistance is borne out of uncertainty. The uncertainty in question is related to whether or not the potential risks associated with adopting a more innovative approach to design will affect the final grades and prospects of the student. In the original programme over-complexity added to the uncertainty as students and staff alike found it difficult to navigate an innovative pathway through a highly fragmented and complex programme of study. Reducing uncertainty is therefore central to processes of innovation within organisations (Fidler & Johnson, 1984). Uncertainty is in part a function of the number of alternative ideas (complexity) contained in an innovation. With an overly large number of fragmented modules and competing demands students were unable in the early years of the programme to see through the complexity and innovate. Overcoming perceptions of complexity is crucial to inducing the level of involvement needed for successful innovation (Bennis, 1965). Reducing the number of modules and creating a more focused, less complex, programme opened the door for greater student involvement in the innovation process.

b. Involvement

Involvement refers to the active participation in innovation processes resulting from a psychological acceptance of the importance of the innovation to the individual and to the organisation (Fidler & Johnson, 1984). Involvement by all relevant stakeholders in an academic community is essential for innovation to take root. The literature identifies involvement as a critical factor in the receptivity of organisational members to innovations (Leonard-Barton & Sinha, 1993). The role of staff/student forums and programme management committees is essential in engendering healthy participation in the innovation process. If students and academics are to rise to the challenge and a culture of innovation is to flourish then both groups need to be persuaded of the benefits and become actively involved. Participation and persuasion have been related to the implementation of change efforts in organisations (Nutt, 1986). In the introduction of a new TLA strategy both the student body and the Faculty need to be fully engaged. Old habits need to be put aside and new ones embraced. Within the major project, teaching strategies were developed to emphasise innovation and risk taking. Students were given more time to develop through self-discovery and 'trial and error'. The assessment process was structured to reward innovation and experimentation.

c. Personal Salience

Salience refers to the perceived importance of an innovation and it has two dimensions: importance to the individual, especially in terms of career advancement, and importance to the culture and goals of the organisation. Performance concerns have been found to be critical factors related to the adoption of innovations (Lewis & Seibold, 1993). Taking these issues on board it was clear that the individual student needed to be given assurances that innovation would be rewarded. The cultural shift required is significant as it requires marking schemes to be developed which reward design innovation at a process level as much as at the final outcome level. The salience of activities related to the culture and to the goals of organisations certainly has been seen as a major motivating force, at least in successful companies (Deal & Kennedy, 1982). This can be seen to be equally true of an academic institution.

5.2.2 Revised Communications

The review conducted in Phase 0 identified the communication deficit in the original programme. An increased understanding of the central role that communication plays in innovation has important implications, both theoretical and pragmatic. Communication is the primary tool used to secure the participation of others in informally generated innovations (Kanter, 1983). With the Major Project identified as the primary vehicle for the development of innovation, a number of clear opportunities were identified: project selection and supervision.

Communication in Project Selection

Within a product design degree students traditionally select and formulate their own project briefs. The selection is influenced by a number of factors: availability of resources, expertise within the supervision team, the student's own abilities and the student's experience of real world problems. Phase I introduced the requirement that students undertake projects that will be innovative as well as academically demanding. The project may be formulated through a variety of means – student idea, industrial liaison, staff-student discussion – or a combination of these means. The ultimate approval of the project to be undertaken rests with the supervising team and the Project Director. Through this mechanism the project aims and objectives are negotiated to ensure every opportunity exists for innovation.

Communication in Project Supervision

Within the Major Project stage students work with the minimum of direct supervision in the synthesis of a design solution and the formulation of an appropriate business strategy based on the results of their investigation. Face-to-face channels are crucial to the formation of coalitions which support an innovation. Because new ideas are risky, students initially share their ideas with members of their immediate network of interpersonal contacts. The role of the supervisor is to act as facilitator as well as mentor to this process. Face-to-face communication provides the support an individual needs to reach other individuals to whom they are not strongly tied by friendship or other relations (Ray, 1987). Communication plays a key role in overcoming resistance to innovations and in the reduction of uncertainty on the part of both the student and the academic. The very complexity of most student innovations may require more intensive interpersonal interaction with a team of supervisors to arrive at high-quality decisions. In the academic environment there may be resistance from the student to engage too closely with the academic for fear of jeopardising grades and there may be difficulties due to time limitations for the supervisor to commit sufficient time to the project. However, direct interpersonal communication is necessary for complex, risky and highly technical innovations (Dearing, et al, 1994). In these cases the systematic use of feedback with more personalised contact is an essential factor in the generation of innovation.

5.3 New Modular Structure

As can be seen from the following module structure table (Figure 5.1), the fragmentation evident in the original structure has been ameliorated, the teaching of industrial design theory expanded, and time and space created for reflection. In an industrial design programme a unique blend of engineering and art coalesce. For the undergraduate it provides a challenge in balancing rational calculated scientific development with intuitive creative expression. Students are often unwilling to go out on a limb for fear of jeopardising their grades. The role of the academics in assessing innovation is vital. The programme structure and assessment criteria need to be conducive to the encouragement and reward of innovation. The work of Zaltman et al (1973) and Drucker (1985) was referenced in support of a teaching, learning and assessment strategy conducive to innovation.

Phase 1 – BSc (Hons) Product Design (1997-2000)					
Part 1		Part 2			
Year 1 - Level 1		Year 2 - Level 2		Year 3 - Level 3	
Semester 1	Semester 2	Semester 1	Semester 2	Semester 1	Semester 2
PD101 Design Studies 1	PD106 Design Business I	PD201 Design Studies 2	PD206 Design Management	PD301 Design Studies 3	
ID102 Introduction to 2D & 3D CAD	PD107 3D CAD 1	PD202 3D CAD 2	PD207 3D CAD3		
PD103 Workshop Practice	PD108 Design Practice 1	PD203 Design Practice 2	PD208 Group Design Practice	PD303 Minor Project	PD306 Major Project
PD104 Approaches to Design	PD109 Product Design 1	ID204 Product Design 2	ID209 Product Design 3		
PD105 Introduction to Product Technology	PD110 Product Technology 1	PD205 Product Technology 2	PD210 Product Technology 3	PD305 Emerging Product Technologies	

Innovation Centred Modules

Figure 5.1 New BSc (Hons) Product Design Structure (Eagle & Walsh 1997)

As identified in 5.2.1.a over-complexity is a barrier to innovation and the adoption of innovative practices. The new modular structure introduced in October 1997 focused the indicative content (curriculum) into standardised discrete units of assessment (modules). All taught modules were standardised on the 12-credit model with clear themes running through from year one to year three. This provided students with a clear understanding of the relationship of the taught modules. The five themes establish route maps by which undergraduates and academics navigate towards the ultimate fulfilment of the programme aims and objectives in the Major Project. Innovation theory was implicit in the structure of level 4 and 5 and explicit in level 6.

5.4 New Study Environment

5.4.1 Location of Study Facilities

Prior to 1997 the studio provision had consisted of three design studios located in two separate buildings at opposite ends of the campus. Workshop facilities comprised of two engineering workshops supported by a solitary technician/machinist. The Information Communication Technology (ICT) provision was divided into word processing/internet and CAD was divided between the library and a small (12-seat) UNIX lab on the floor above the main design studio. The consequences of this dispersal of resources and facilities were evident in the lack of cohesion and the exacerbation of the fragmented teaching, learning and assessment environment. This culture and climate led to the frustration of innovation and a lack of innovative dynamism. The review in 1997 brought in a series of changes to the study environment. The design studios were consolidated on two floors in 'B-Block' on the Mount Pleasant Campus. This reorganisation allowed for vastly improved communication between year groups and between academics and undergraduates Figure 5.2). The expansion of workshop facilities begun in 1995 was completed in the summer of 1997. The ICT and CAD provision was expanded to create a 25-seat PC-based CAD studio.

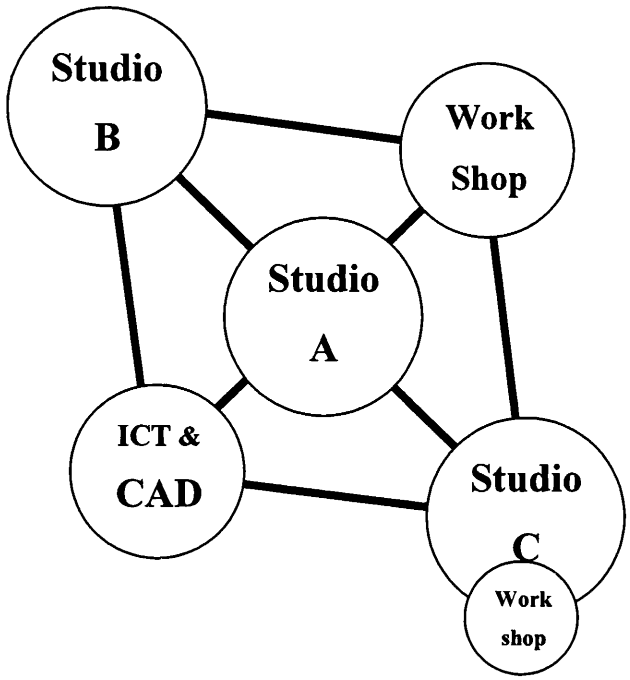


Figure 5.2 Post 1997 Mapping of Student Activity and Resource Location

The impact of the new facilities was immediate and profound. In purely practical terms the reduction in movements around the campus allowed for more efficient and effective use of time. The end of the 'kit-bag' culture where students moved from one end of the campus to the other with their work in a bag was a significant improvement. Establishing base studios in one central location allowed for the fluid exchange of ideas and debate across year groups.

5.4.2 Impact of New Facilities on Design Process

The nature of the design process changed as a direct consequence of the new facilities. Students and staff were able to engage with appropriate resources to facilitate their project developments without having to 'pack up' their work in one area and move to the next. Numerous studies have demonstrated the importance of organisational environment in innovation (for example Balachandra and Frier 1997). In each of these studies the requirement for the innovation environment is identified. The importance of establishing the right physical environment is essential if a sustainable innovative culture is to be developed. The consolidation of design studios, CAD studio, workshops and staff rooms in one discrete centre enabled a culture of innovation to emerge. The design process was liberated and outcomes improved.

5.5 *Innovation Outcomes*

5.5.1 Peer Recognition (Awards and Competitions)

Prior to 1997 the product (industrial) design programme at Swansea had won only one award – the 1997 WDA-sponsored Technology Award for Design and Product Engineering. From 1998 significant increases were seen in the level of peer recognition.

Gary Phillips	Winner of WDA Technology Prize: Design & Product Engineering	1998
James Tomaszewski	Winner of WDA Technology Prize: Design & Product Engineering	1998
Matthew Teeling	Winner of WDA Technology Prize: Design & Product Engineering.	1999
Phillip Sage	Short listed in RSA Design Awards: Transportation Design	2000
	Short listed in Peugeot Design Awards: Recreational 4x4	2000

Figure 5.3 Design Innovation Awards 1997-2000

The rise in awards won by graduates of the programme provided a strong indication of the impact that the changes implemented had on innovation. If this small sample of projects can be said to exhibit innovation due to recognition by their peers, what of the remainder? If the changes implemented in 1997 have made an impact on the innovativeness of the student then it should be measurable across the cohort.

5.5.2 Project Innovation

As in phase 0 the projects were collated (Appendix 2, p.266) and evaluated against two scales. The first was the Altshuller Scale. Initial results indicated a positive shift in the level of innovation present. Values moved to the right resulting in an increase in level 2 innovations. As all projects fell within the level 1 to 3 range there was evidence that the results were producing a localised 'normal' distribution but, taking the scale as a whole, the distribution remained in the classic J-shaped curve.

Altshuller's Five Levels of Innovation – Phase 1				
Level 1	Level 2	Level 3	Level 4	Level 5
26	34	16	0	0
Phase 1				
Level 1	Level 2	Level 3	Level 4	Level 5
34.21%	44.74%	21.05%	0.0%	0.0%

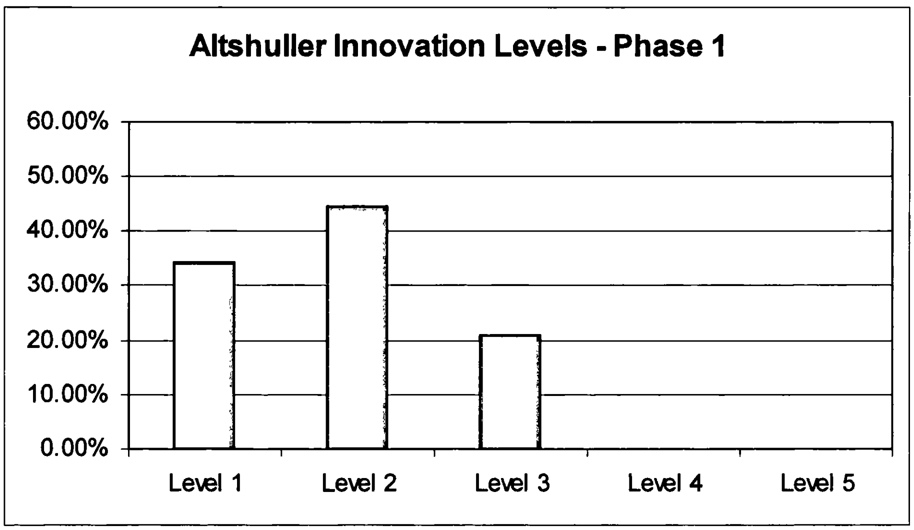


Figure 5.4 Innovation against the Altshuller Scale 1997-2000 (Phase 1)

The second scale produced a wider distribution of values. Projects were identified in each of the five levels. Despite the encouraging shift in the distribution of values the distribution remained in the J-shaped curve. The histogram gave positive feedback of a qualitative nature but added little of statistical significance to the study.

Phase 1				
Level 1	Level 2	Level 3	Level 4	Level 5
39	17	15	4	1
Phase 1				
Level 1	Level 2	Level 3	Level 4	Level 5
51.32%	22.37%	19.74%	5.26%	1.32%

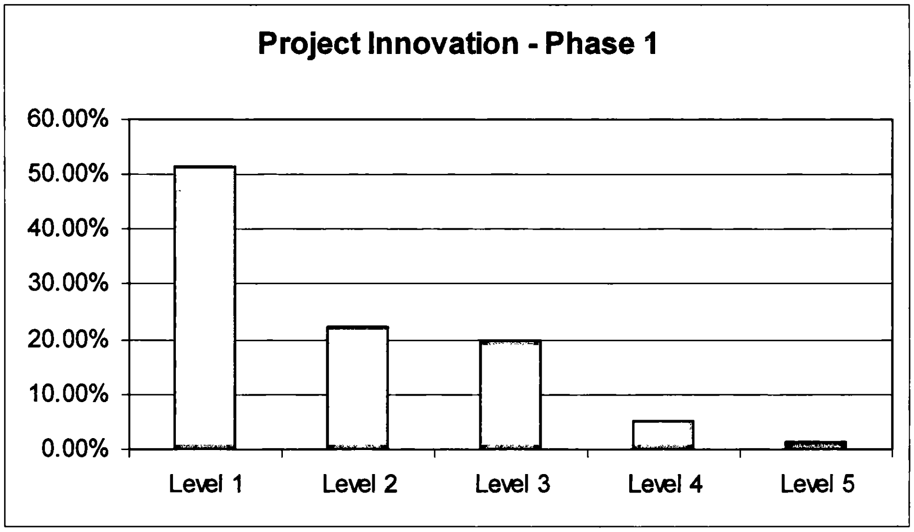


Figure 5.5 Innovation against the Likert Scale 1997-2000 (Phase 1)

5.6 *Review of Pedagogy*

At the commencement of Phase 1, five objectives were identified as mechanisms for the improvement of innovativeness amongst the undergraduates at the heart of the study:

- Reorganisation of the modular structure and TLA strategy
- Removal of superficial content
- Reorganisation of the study environment
- Increased studio-based studies and activities
- Restructuring of the Major Project module to include an innovation-centred approach to teaching, learning and assessment

5.6.1 Review of TLA Strategy

Following the 1997 review a new streamlined modular structure was introduced. This structure emphasised the teaching and learning of core design thinking and skills. Emphasis was transferred from electronic product design to a more open innovation-led approach. The work of Zaltman, Duncan, & Holbeck, 1973; Amabile, 1988; Van de Ven et al, 1989; King, 1990; West, 1990; Anderson & King, 1993 was used as the basis for creating a TLA strategy where industrial design innovation could be nurtured. As reported in Chapter 2, an innovation mindset is an attitude, a state of mind, which should permeate the entire institution. The hallmarks of this mindset can be seen in the way individuals at all levels in the organisation interface with each other, (Kuczmarski 1996). In this case the 'organisation' is the entire programme team comprising students, academics and professional support staff acting as a unified body. This team works to a course document and the learning experience leads to a final assessment, which is then validated by the external examiner(s). Innovation does not only embrace the entire course team but must also be reflected in the documentation and is a spirit that should be shared by the external examiners. Certain imposed features such as modularity and semesterisation tend to suppress innovation by creating artificial barriers in what should be a holistic educational experience.

5.6.2 Review of Communication

The experience of Phase 1 was one of significant improvements in innovation culture brought about by the changes to the modular scheme and environmental changes due to the relocation of facilities. Allied to these was the improved communication of ideas and opportunities for negotiated collaboration facilitated by closer physical interaction. Key principles of innovation within an individual and an organisation include curiosity, questioning, experimentation, self-motivation, vision, passion, flexibility, commitment, resilience and perseverance. These principles or qualities can occur 'naturally' but more often require nurturing if they are to become fully employed. The improved communications within the programme and across the Faculty enabled these qualities to be nurtured within a supportive environment where face-to-face interaction was readily accessible.

5.7 Review of Programme Structure

The programme structure developed as a result of the phase 0 review facilitated significant improvements in the student experience and the innovation environment. The development of an academic community where innovation in both process and outcome is valued was a necessary first step towards nurturing innovation. The question of how to nurture innovation within an educational environment must be preceded by the question 'why do we need to be innovative?' This can be summarised in the phrase 'to survive'. "Innovation is the key to competitiveness, and businesses need to innovate if they are to succeed." (Battle 1998).To the academic institution innovation is vital if it is to remain at the forefront of its discipline. To the undergraduate designer innovation is vital if he/she is to produce a successful major project and portfolio, and compete in what is an increasingly global job market. Achieving and maintaining a culture of innovation depends upon all parties being fully committed. The challenge of an academic programme where students study for three years then move on is how to maintain continuity. It is vital to perpetuate the culture by encouraging interaction between year groups and constant communication amongst academics. It would be wrong to conclude that once established this culture of innovation must be maintained as a status quo. Indeed, the very nature of this culture is that it is constantly changing. The role of the academics is to ensure that teaching; learning and assessment strategies constantly evolve so as not to frustrate the innovative spirit. The modular structure implemented in 1997 was therefore in need of revision for the next phase. Undergraduates need physical and perceptual space to be able to experiment and challenge the boundaries. This can only be achieved if all relevant stakeholders are involved.

5.8 Review of Study Environment

The improvements made at the beginning of Phase 1 and during the three years' duration of the phase were extensive and significant. Consolidation of the studios improved interaction between the year groups and allowed for improved communication. The enlargement of both workshop and CAD facilities led to improved working practices. Students no longer needed to factor movements between buildings into their daily plan. The proximity to the studios of facilities essential for product realisation created opportunities for spontaneous and serendipitous collaboration and innovation. This cultural shift led to changes in attitudes amongst both students and academics. Attendance patterns changed with students spending more time in the studios and workshops. These improvements proved to be the catalyst for further developments in future phases.

5.9 Development of a Revised Pedagogy

Following extensive reviews of the structure and pedagogy employed in phase 1 the degree of change required in Phase 2 was minimal. Primarily the need identified was one of continued clarification. The focus shifted from major structural change to accentuate refinement of the model. An emphasis on nurturing innovation emerged, replacing the need to create a culture and environment able to support innovation. The revised pedagogy encapsulated in the amended modular structure is discussed in the following chapter.

5.10 Summary of Phase 1 Outcomes

The object of this phase was the implementation of an industrial design programme to facilitate the development of innovativeness in the student body. The outcomes of that implementation were embedded in a revised programme document produced in June 1997 and delivered for three years. This chapter has discussed the implementation of the 1997 structure and its impact on student innovation. The chapter has considered the impact of the new structure on innovation outcomes. To a large extent these have been positive, and qualitative studies indicate the improvement in innovation outputs is measurable.

The outcomes identified from Phase 1 are:

- New pedagogy was implemented
- A new study environment created
- Communication and internal networking has improved
- Peer recognition in terms of student awards has improved
- Overall level of innovation has increased

The review of Phase 1 concludes that the modular structure be refined and updated in light of ongoing developments in practice – that the emphasis be placed upon nurturing innovation rather than simply creating space for innovation.

These actions were implemented from the beginning of the 2000/2001 academic year. Chapter 6 describes the implementation of the actions and evaluates the outcomes.

6 Development of Innovation Pedagogy Phase 2 (2000-2004)

"Continuity between tradition and the present is important."

(Pia Wallen, 2001)

6.1 Introduction

Phase 1 created the conditions for innovation to flourish and succeeded in expanding the scope for innovation within the department. During Phase 2, the primary goals were to stimulate, incubate and nurture student innovation and create a momentum for continued development of the innovation culture. The role of the academics in accepting and encouraging innovation is vital. The programme structure and assessment criteria need to be conducive to the encouragement and reward of innovation. Stimulating a culture of innovation depends upon all parties being fully committed.

6.2 Implementation of a New Pedagogy

The review of Phase 1 highlighted an important imperative in the development of an innovative industrial designer. If innovation is to flourish it is vital to encourage the integration of projects across modules and even across year groups. The role of the academic is vital in this process. Innovation doesn't end with the student project itself but must extend to embrace the mode of delivery, assessment and feedback. Both designer and design need to be nurtured to achieve an innovative outcome. The challenge of an academic programme where assessments have to be made and deadlines met is how to create the time to allow for the incubation of innovative ideas. The introduction of innovation theory into the curriculum was integrated into the design studio theme. This enabled staff and students alike to develop their approach to innovation in a less pressurised atmosphere than that presented by the major project alone. To differentiate the phases the programme title was changed. The new title represented a shift away from a product-centric approach to a solution-based approach where research was unhindered by a prescriptive product based goal. The new title, BSc (Hons) Industrial Design along with re-titled modules provided fresh impetus to the development of the thematic study area. A sister programme in automotive design was also launched. The automotive design programme emphasised a pedagogy which was altogether more traditional than the industrial design approach. This provided the research with an opportunity to run comparative tests on two design programmes where the only difference is the approach to innovation.

6.3 New Modular Structure

A key question relating to the nurturing of innovation within an educational environment is that of risk tolerance. In an industrial design programme a unique blend of engineering and art coalesce. For the undergraduate it provides a challenge in balancing rational calculated scientific development with intuitive creative expression. As identified in 5.3, students are often unwilling to go out on a limb for fear of jeopardising their grades. The role of the academics in assessing innovation is vital. The programme structure and assessment criteria need to be conducive to the encouragement and reward of innovation. The second iteration of the programme structure resulted in the following modular structure (Figure 6.1). The revised programme and its associated teaching, learning and assessment strategies allowed for greater integration across modules resulting in students becoming more open to innovate and less risk averse.

Phase 2 – BSc (Honours) Industrial Design (2000-2004)					
Part 1		**Part 2**			
Year 1 - Level 1		**Year 2 - Level 2**		**Year 3 - Level 3**	
Semester 1	**Semester 2**	**Semester 1**	**Semester 2**	**Semester 1**	**Semester 2**
ID101 History of ID	**ID106 Marketing**	**ID201 Design in Context**	**ID206 Design Management**	**ID301 Ethics & Philosophy**	**ID306**
ID102 Introduction to Computer Graphics	**ID107 3D CAD Solid Modelling**	**ID202 3D CAD Visualising**	**ID207 Advanced 3D CAD**	**ID302**	**ID307**
ID103 Workshop Practice	**ID108 Design Practice 1**	**ID203 Design Practice 2**	**ID208 Group Design Practice**	**ID303 Minor Project**	**ID308 Major Project**
ID104 Approaches to Design	**ID109 Design Methodology**	**ID204 Design Principles**	**ID209 Design Development**	**ID304**	**ID309**
ID105 Introduction to Technology	**PD110 Mechanics & Electronics**	**PD205 Materials & Manufacture**	**PD210 Product Engineering**	**ID305 Emerging Technology**	**ID310**

Innovation Centred Modules

Figure 6.1 BSc (Hons) Industrial Design Structure (Walsh & Jenkins 2000)

The semesterised modular structure developed in Phase 1 was retained in order to comply with the Institute's Quality Handbook. Working within this restriction the team reorganised the taught material and integrated innovation methods into the core design methods modules (ID109, ID204 and ID209). The final year major and minor projects were restructured to accommodate a research and innovation-led approach. The emphasis of the revised modules (highlighted in grey in Figure 6.1 above) was the move away from a product-centric approach to one based upon the identification of opportunities and needs. Two important factors to emerge in this second phase were:

- The need to establish a culture of innovation that was organic and self perpetuating
- The need to develop methods to measure innovation outputs

6.4 Innovation Culture

Key principles of innovation within an individual and an organisation include curiosity, questioning, experimentation, self-motivation, vision, passion, flexibility, commitment, resilience and perseverance. The experience of the programme team in Phase 2 was crucial in reinforcing the importance of ensuring that freedom to innovate was embedded in the programme culture. Two areas emerged as opportunities to encourage an attitude of innovation and a means of benchmarking progress. The first was the development of a research strategy aimed at involving undergraduates in publishing and presenting at international conferences. The second was the introduction of an Intellectual Property Rights (IPR) scheme aimed at protecting student innovation.

6.4.1 Research Strategy

In pursuit of a culture of innovation the team identified research as an opportunity for externalising student expectations and raising the value of their intellectual engagement. The strategy was conceived as a means of integrating the second year 'Design in Context,' 'Design Principles' and 'Design Development' modules to encourage the students to further explore their practical innovation with a philosophical and research-centric approach. The objectives were and are to encourage students to identify conferences or journals with an industrial design theme and submit a paper for review and publication. The process involves:

1. Identification of suitable conference
2. Research and preparation of a paper for submission
3. Paper is submitted via the Design in Context tutor
4. The original paper is retained for assessment purposes
5. A suitable Academic is identified and added as a second author
6. Subject to revision and internal approval the abstract or full paper is submitted
7. If the paper is successfully accepted for presentation or publication the Academic and student authors attend the conference

The benefits of the scheme are profound and far reaching. To the entire student body the scheme encourages each individual to identify and value the created knowledge. To the successful individual it provides experience of academic publishing and the character-building experience of presenting at an international conference. To the Academic it provides a fresh challenge and an opportunity to develop their research interests in a new direction. Thus the opportunity for innovation is enhanced as new fields of interest and knowledge are opened up. The first successful event was the Cumulus conference held at Oslo School of Architecture and Design in May 2004. A total of six papers were presented. Of these one was by an academic, four by masters students and crucially one by a second-year industrial design student.

Figure 6.2 Steve White, Hilde Nordli, Paul Gwilliam, Alex Sullivan, Chris Wyatt and Ian Walsh. Oslo 2004.

The value of student participation in research and conference publishing is difficult to quantify. What can be said is that the impact on the student's academic development is far reaching and significant. The student learns to value their ideas and intellectual capital which in turn leads to improved results in subsequent studies.

6.4.2 Intellectual Property Rights (IPR) Scheme

Patenting is an internationally recognised method of protecting invention and thereby serves as a useful indicator of innovation. The patent system is one method organisations use to protect their inventions. Patents are systematically registered by government bodies such as the UK's Intellectual Property Rights Agency (Patent Office). The origin of the patent system in the UK goes back to medieval times when the monarch granted individuals monopolies for a variety of purposes. The actual term 'patent' is derived from the Latin 'litterae patente' meaning an open letter intended for public display. Over time it became abbreviated from 'letter patent' to just patent. The function of patents is to stimulate and encourage innovation. Any innovator faces the problem that, if the invention is a success, it may be copied and the innovator may derive little in the way of reward for his/her hard work and effort in developing it. If the likelihood of copying can be reduced then the chances of financial success for the innovator are greater. This is actually a matter of public policy, as the state has to weigh the benefit to the public interest of incentivising innovators and encouraging innovation against the cost (to the public) of a slower rate of diffusion (i.e. take-up) of the innovation. If they are duly processed, classified and organised, patents provide a unique source of information on industrial innovation. The OECD Patent Manual (OECD 1994) provides guidelines for the use of patents as well as a guide to the patent-based literature (see also Basberg 1987 and Griliches, 1990). Like any other innovation indicator, patents have advantages and disadvantages, which it is useful to summarise. Their advantages are:

- They are a direct outcome of the inventive process, and more specifically of those inventions which are expected to have a commercial impact. They are a particularly appropriate indicator for capturing the proprietary and competitive dimension of technological change.
- Because obtaining patent protection is time-consuming and costly, it is likely that applications are filed for those inventions which, on average, are expected to provide benefits that outweigh these costs.
- Patents are broken down by technical fields and thus provide information not only on the rate of inventive activity, but also on its direction.
- Patent statistics are available in large numbers and for a very long time series.
- Patents are public documents. All information, including patentees' names, is not covered by statistical confidentiality.

Their disadvantages are:

- Not all inventions are technically patentable.
- Not all inventions are patented. Firms sometimes protect their innovations with alternative methods such as Design Registration.
- Firms have a different propensity to patent in their domestic market and in foreign countries, which largely depends on their expectations for exploiting their inventions commercially. In each national patent office, there are many more applications from domestic inventors than from foreigners.
- Although there are international patent agreements among most industrial countries, each national patent office has its own institutional characteristics which affect the costs, length and effectiveness of the protection accorded. In turn, this affects the interest of inventors in applying for patent protection.
- The cost of patenting often prevents small firms or sole innovators from patenting their innovation resulting in a skewed distribution of patents and the consequent under-recording of actual innovation.

Four different measures have been used to increase the accuracy of patent counts.

- **Patent citations:** the count of citations of a patent in subsequent patent literature. This is an indicator of the technological impact of the patented invention (Trajtenberg, 1990).
- **Renewal fees:** total cost and the number of years for which the patentee pays renewal fees to maintain the legal value of the patent. This gives information on the economic value attributed to the invention (Pakes and Simpson, 1989).
- **Patent families:** mapping the number of countries to which a single patent application has been extended makes it possible to identify the subset of patents applied for in all major markets. This shows the areas of exploitation of an invention and offers a more accurate database for international comparisons (Schmoch and Kirsch, 1993).
- **Patent claims:** the number of claims made in each patent application, which gives information on the range of novelties in the patent document. Research has shown that the average number of claims per patent has considerably increased and that significant differences are found across countries (Tong and Frame, 1994).

Historically, the protection of Intellectual Property Rights by industrial designers has been limited. Traditionally, industrial designers have been employed or commissioned by organisations that retain rights to the work. In an academic institution undergraduates often sign away the rights to their work simply by enrolling on their programme. The institution retains the rights to the work but rarely invests the necessary time or resources to cultivate the IPR into wealth creating opportunities. Swansea Institute chose not to retain the IPR of its undergraduates. The opportunity therefore existed for the students to protect their own IPR. As can be seen from the following graph, few students took up the opportunity.

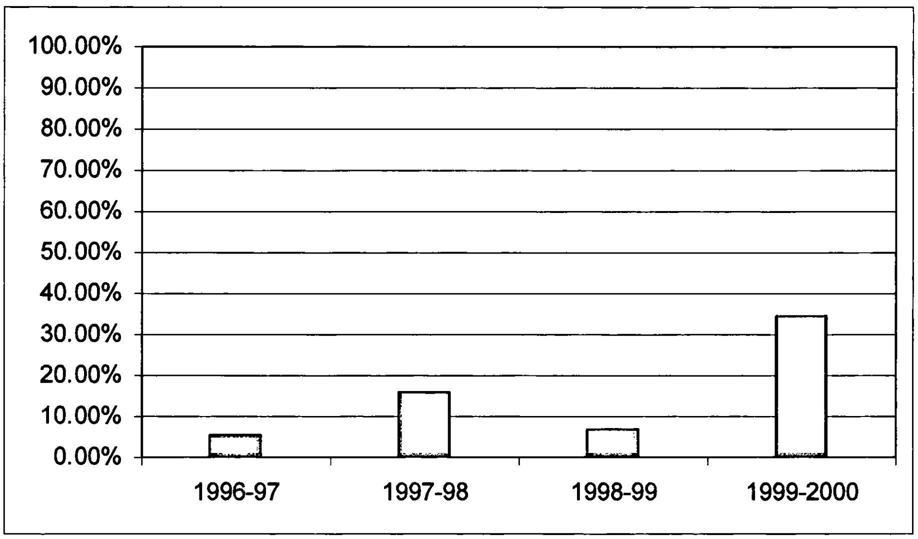


Figure 6.3 Student Patent Applications 1997-2000

In 1999 the City and County of Swansea launched its Intellectual Property Scheme. The aim of the scheme was to support and fund the protection of IPR within the county. Based at the Institute, the scheme gave the programme the ideal vehicle for raising the number of patent applications. Under the Institute's IPR Scheme, Swansea Institute's School of Industrial Design in collaboration with Swansea (now Cardiff) based Patent Attorneys Urquart Dykes and Lord submits an annual block patent application. A strong emphasis was placed on the protection of IPR and undergraduates were encouraged to register their designs and apply for patents. This resulted in the percentage of Industrial Design students submitting patent applications rising to 100% in the 2002-2003 academic year. The following protocol was developed to encourage patenting specifically within the School of Industrial Design:

- Students are encouraged to consider the novelty of their ideas
- Students are encouraged to 'professionalise' their view of IPR
- Students are given project guidelines that promote the identification of potential innovation and IPR as an element of project selection prior to commencing their major project
- The School does not select or screen the projects for patenting
- The patent application is a prescribed deliverable but is not assessed

The IPR scheme encourages innovation on several levels:

- It encourages students to strive for the most innovative solution
- It encourages the students to challenge received approaches to problem solving
- It teaches the students to value their ideas

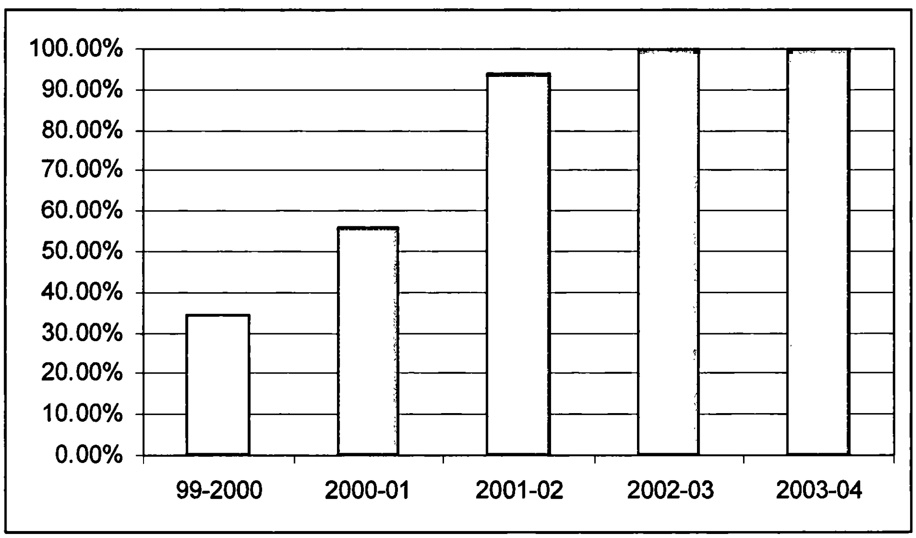


Figure 6.4 Student Patent Applications 2000-2004

Between 2000 and 2004 the percentage of industrial design students taking advantage of the opportunities afforded by the scheme grew to 100%. That is to say, all final-year students chose to submit a patent application prior to graduation.

"With increased levels of innovation comes an increased opportunity for protecting and exploiting the generated intellectual property" (Walsh & Clement 2001).

The effectiveness of the scheme can be measured in a number of ways. Success is not solely limited to the commercial exploitation of the IPR. The scheme can be seen to have encouraged the student body to be more aware of IPR issues, to be pro-active in seeking novel solutions to design opportunities, to be more entrepreneurial in outlook and to approach their work with far more rigour. Detailed reporting and analysis of the outcomes of the IPR Scheme are considered in chapter 7.

6.5 Innovation Outcomes

Phase 2 saw an increased awareness of innovation, an increase in the number of patent submissions, students successfully presenting at conferences and the development of a dynamic culture of innovation. The question remains 'how can one recognise an innovative idea?' This involves benchmarking against indices of innovation. The principal indicators used within this project are Altshuller's five levels of innovation and a five-point Likert scale derived from the OECD's Oslo Report. Two additional indicators (patents generated and awards won) were included in the measurement of innovation outcomes in Phase 2.

In Phase 0 and Phase 1 industrial (product) design projects were evaluated against two scales, the Altshuller and Likert scales. Phase 2 introduced an additional factor. This phase saw the introduction of a comparative group against which to benchmark. The original group studied were all BSc (Hons) Product Design students. A change of title in 2000 resulted in the switch from product to industrial design and the development of a new programme in Automotive Design. By the end of Phase 2, the opportunity arose to conduct parallel screening of students following the BSc (Hons) Automotive Design programme. The advantage of studying this group is that they study the same set of modules but without the focus on innovation embedded in the industrial/product design programme. The data was collated and summarised for analysis (Appendix 3, p.268).

6.5.1 Comparative Analysis of Innovation against Altshuller Scale

As can be seen from the summary of Altshuller's results (Figure 6.5) a clear correlation between Altshuller's findings and the results of Phase 2 can be seen. What has emerged is a pattern whereby 70-75% of final year student projects can be classified as level 1 and level 2 innovations. What can also be seen is that approximately 20-25% are level 3 innovations. The key figure for the academic team involved is the 5% who are producing level 4 innovations according to Altshuller's criteria.

Altshuller's Five Levels of Innovation – Phase 2					
	Level 1	Level 2	Level 3	Level 4	Level 5
Industrial	34	34	17	2	0
Auto	11	13	6	0	0
	Phase 2				
	Level 1	Level 2	Level 3	Level 4	Level 5
% ID	39	39	20	02	0
%Auto	37	43	20	00	0

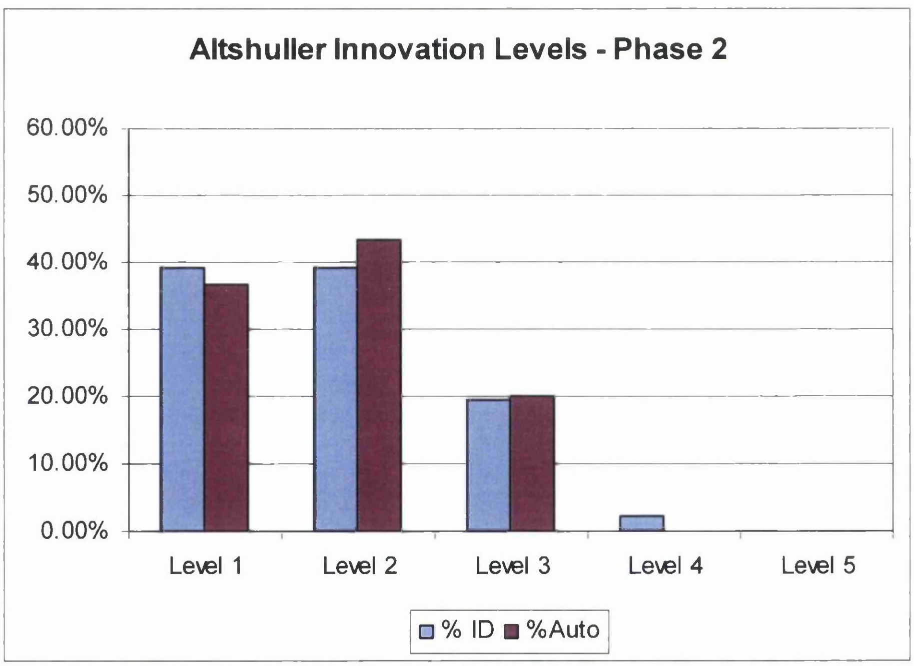


Figure 6.5 Innovation against the Altshuller Scale 2000-2004 (Phase 2)

6.5.2 Comparative Analysis of Innovation against Likert Scale

The Likert analysis typically produces a wider spread of outcomes than the more prescriptive Altshuller scale. The Phase 2 outcomes indicate a shift towards a normal distribution of values. It is true to say that there is a skewed distribution towards the lower end of the scale but this is to be expected. In the final analysis the projects under scrutiny are undergraduate and unproven in the real world. Despite the best efforts of the students under consideration it is very difficult to prove the potential for a project to be implemented or adopted by the market. Only the market itself can confirm this.

Phase 2					
	Level 1	Level 2	Level 3	Level 4	Level 5
Industrial	20	22	28	14	3
Auto	6	15	4	4	1
	Phase 2				
	Level 1	Level 2	Level 3	Level 4	Level 5
% ID	23	25	32	16	03
%Auto	20	50	13	13	03

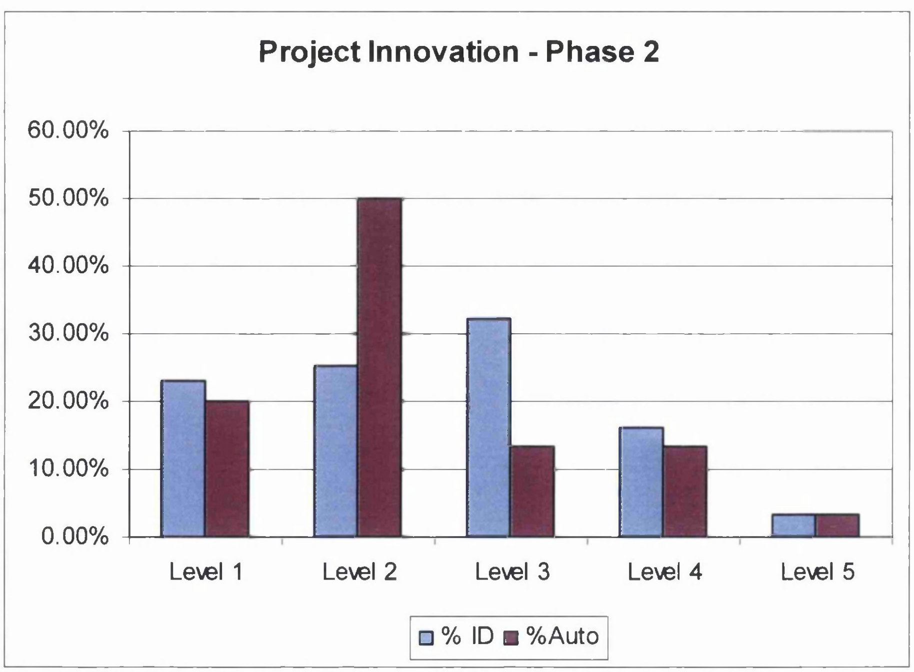


Figure 6.6 Innovation against the Likert Scale 2000-2004 (Phase 2)

What also emerged from the analysis of the Likert scores was the difference between the industrial (product) design outputs and the automotive design student outputs. Whereas the industrial (product) designers had begun to demonstrate a normal distribution, the automotive designers were clearly skewed towards the lower end of the scale (a classic J-shaped curve).

6.5.3 Peer Recognition – Innovation Awards

WDA Technology Prize. The programme team targeted the WDA Technology Prize awards as a means of externally benchmarking the innovation of the final projects. The awards were made annually to Welsh Universities and Institutes of Higher Education to recognise the innovation of final year undergraduates. Six awards were given in a range of categories:

- Innovation in Design
- Innovation in Materials
- Innovation in Healthcare
- Innovation in Computing Science
- Innovation in Communication
- Future Wales Award

A panel of experts drawn from industry and the Welsh Development Agency made the awards based upon the level of innovation and potential for commercial development. Taking Zaltman's definition of innovation as 'any idea, practice, or material artefact perceived to be new by the relevant unit of adoption' (Zaltman et al, 1973) the WDA awards provide us with a useful external measure of innovation. As with the patent scheme all students are encouraged to enter and there is no screening or selection. The outcome of the School of Industrial Design's participation in the WDA awards can be seen in the graph (Figure 6.7). The graph plots the number of award winners from the School of Industrial Design compared to winners from other University departments across Wales. Due to funding restrictions the award scheme ceased in 2003.

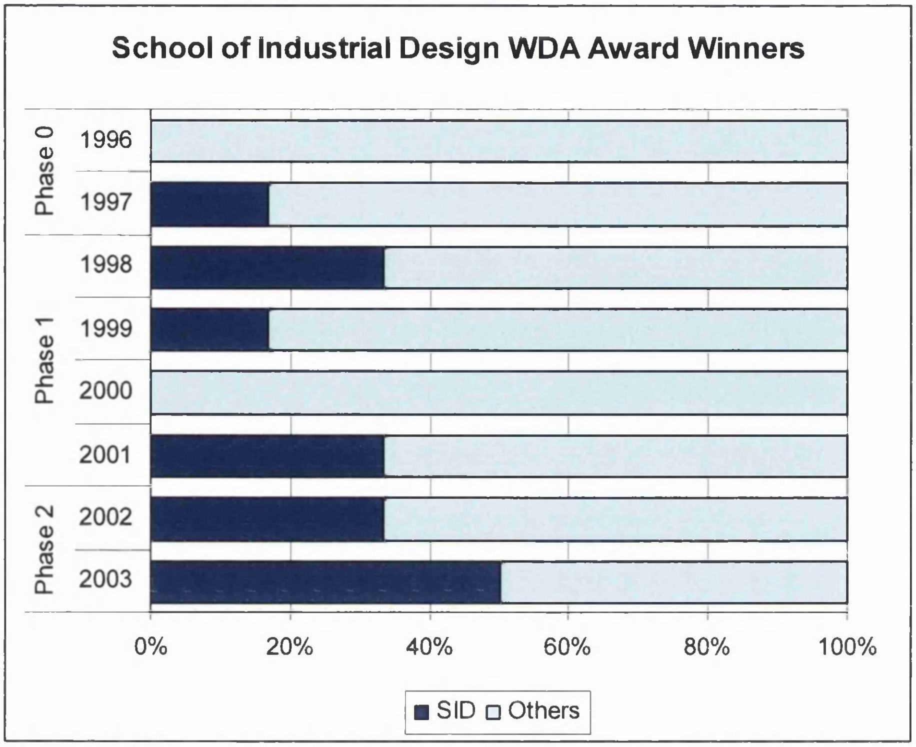


Figure 6.7 WDA Award winners from Swansea School of Industrial Design compared with all other university departments across Wales

With the cessation of the award scheme the School lost the opportunity to benchmark the innovativeness of its student outputs against its Welsh peers.

Figure 6.8 Alex Sullivan, Ryan Flynn and James Cooper Swansea Institute's WDA Award Winners 2003

(A new awards scheme for product design was launched in 2007 by Design Wales. The 'Ffres' Awards attracted submissions from all Wales' industrial design programmes. The School of Industrial Design at Swansea Institute had two projects in the final shortlist of three and took first place at an awards ceremony at the Newport Centre in June 2007.)

The WDA Award was not the only source of external peer recognition. During the period under review eight other students achieved notable success in external awards.

James Cooper	**Winner of WDA Technology Prize: Innovation in Design.**	**2003**
Ryan Flynn	**Winner of WDA Technology Prize: Innovation in Use of Materials.**	**2003**
Alex Sullivan	**Winner of WDA Technology Prize: Future Wales Award.**	**2003**
Mark Hammill	**Shell LiveWire Young Entrepreneur of the Year Awards – 'Best Use of Technology'.**	**2003**
Mark Hammill	**Winner of WDA Technology Prize: Manufacturing and Product Engineering.**	**2002**
Neil Giddy	**Winner of WDA Technology Prize: Innovation in Design.**	**2002**
Neil Giddy	**Finalist in RSA Design Awards: Action Man.**	**2002**
Ross Head	**Winner of Audi Foundation: Future of Design Award for Progressive Product Design.**	**2001**
Ross Head	**Winner of WDA Technology Prize: Innovation in Design.**	**2001**
Phillip Sage	**Winner of WDA Technology Prize: Manufacturing and Product Engineering.**	**2001**
Richard Clement George Gee Glenn Drake Jonathan Bailey	**Winners of McKechnie/Luminar: Protective Packaging of Beverages to Combat Date Rape.**	**2001**
Johanna Heinonen	**Short listed in RSA Design Awards: IKEA Furniture.**	**2001**

Figure 6.9 Industrial Design Award Winners 2001-2003

6.6 *Review of Phase 2*

The aim of the review was to assess the impact of the new model on the level of innovation by identifying the factors that played a positive role and those that had a negative one. These were identified as:

6.6.1 Negative Factors

Programme Structure. Modular programmes of study can have a negative effect on innovation. Modularity creates discrete independent 'ghettos' of programme elements that cause the undergraduate to lose sight of the big picture. The implementation of the pedagogical model described in Phase 2 has not fully delivered the desired results. There remains a perception of fragmentation on the part of the undergraduates. Semesterisation, and the resulting division of the programme into 15-week teaching blocks, creates artificial barriers to the free development of ideas.

Over-assessment. The new teaching, learning and assessment strategy developed for the programme is appropriate for determining academic progression and attainment. In terms of the innovation culture it can produce an adverse effect. Undergraduates, ever conscious of grades, tend to 'play safe' and avoid the risk taking essential if dynamic innovation is to flourish.

6.6.2 Positive Factors

Committed Academics. This was key to initiating the initial project and has been essential in the realisation of Phase 2 and its subsequent review. The School and Faculty possess a body of academics with a strong belief in the programme and a commitment to innovate.

Communication. The beginning of Phase 1 of the project witnessed the creation of a consolidated studio, CAD and workshop facility. Phase 2 continued the development of these facilities. A key factor is the proximity of academics to the studios. Staff are accommodated either in offices accessed through the studios or off the corridor linking the studios. This new environment or community, where students and academics work alongside each other, has dramatically improved communication and has thereby supported the emergence of a culture of innovation.

Committed Students. The support of the students ensured that the project was a dynamic collaboration of ideas. Discussions were held with student representatives to discuss the common vision for the programme. This ensured that changes to the structure took full cognisance of students' needs and aspirations.

Support from the Faculty. Faculty support was assured and resources made available. As a result of the success of Phase 2 the Faculty established the School of Industrial Design. This resulted in a strengthening of the culture of innovation and thereby ensured the continued research activity within the industrial design area.

6.7 Module Review

When the original programme was reviewed during Phase 0, a detailed module-by-module review was conducted. At the end of Phase 1, no such review was conducted as the transition from Phase 1 to Phase 2 was evolutionary and involved a degree of 'fine tuning' of the model. The culmination of Phase 2 demanded an altogether more radical review. What had been delivered between 1997 and 2004 was essentially the same programme with some changes of emphasis resulting from the end of Phase 1 review. The following table (
Figure 6.10) summarises the 'root and branch' review of the modules conducted in 2004.

Module Review Summary

Existing Module	Rationale for Change	Proposed Changes	New 'Module'
Year 1 / Level 4 Modules			
ID 101 History of Industrial Design	• Module is purely a historical overview of movements and trends. • Module doesn't reflect upon the development of material culture.	• Update syllabus. • Combine with Marketing to create a single integrated 20-credit module.	IDP 102 History of ID and Material Culture
ID 102 Intro. to Computer Graphics ID107 3D CAD Solid Modelling	• CAD Modules need to be more integrated into design and innovation process.	• Update syllabi. • Combine to create a single integrated 20-credit module.	IDP 104 3D Computer Aided Design
ID 103 Workshop Practice ID 104 Approaches to Design ID 108 Design Practice 1 ID 109 Design Methodology	• Modules need to be more integrated. • Need to increase the ergonomics content. • Modules need to move away from skills development towards knowledge development.	• Update syllabi. • Combine to create a single integrated 40-credit module. • Create new ergonomics module.	IDP 101 Design Methods IDP 106 Ergonomics

ID 105 Introduction to Technology	Response to reports from the external examiners.	Technology stream will be re-structured. Additional fundamental principles added. Module increased from 12 to 20 credits. Material absorbed from PD 110.	IDP 103 Introduction to Technology
ID 106 Marketing	• Response to staff, student and external examiners' comments. • The module isn't integrated into the design structure.	• The syllabus to be updated and integrated into a new module with design history.	IDP 101 History of ID and Material Culture
PD 110 Mechanics & Electronics	Response to reports from the external examiners. To maintain the relevancy of the material to the students' future professional needs these modules needed to be integrated to create a common first year module.	Technology stream will be re-structured. Additional fundamental principles will be included. Some material integrated into level 2 modules.	IDP 203 Material and Manufacturing Processes IDP 214 Mechanics & Electronics

Year 2 / Level 5 Modules			
ID201 Design in Context	• Needs to reflect a more holistic view of contemporary practice. • Needs to reflect the research ethos developed during phase 2.	• Update syllabi. • Add research methods to strengthen its research ethos.	IDP 202 Design in Context
ID202 3D CAD Visualising ID207 Advanced 3D CAD	• Student feedback indicates a desire for more integration between semesters. • Module content needs revising to integrate design process.	• Modules combined. • Syllabi updated. • Design process integrated.	IDP 215 Advanced Solid Modelling
ID203 Design Practice 2 ID204 Design Principles ID208 Group Design Practice ID209 Design Development	• Response to staff and student feedback. • Modules need to be more integrated. • Need to develop a more integrated and inclusive approach. • Development of innovation traits needs to be addressed.	• Update syllabi. • Combine to create a single integrated 40-credit module. • Incorporate elements of design management. • Increase to freedom to innovate. • Incorporate a group project.	IDP 201 Professional Practice
PD205 Materials & Manufacture PD210 Product Engineering	• Advice from external examiners over seven years recommends a new approach to technology.	• Creation of two new modules.	IDP 203 Materials and Manufacturing Processes IDP 214 Mechanics and Electronics
ID206 Design Management	• Need to integrate the material taught.	• Absorb the content within Professional Practice.	IDP 201 Professional Practice

Year 3 / Level 6 Modules			
ID301 Ethics & Philosophy	• Module outcomes to be changed to reflect a more challenging research based approach.	• Update syllabi. • Introduce a research-based assignment. • Increase from 12 to 20 credits. • Focus on BA pathway only.	IDP 304 Design Ethics
ID303 Minor Project	• Need to make the module more of a conceptual exploration of design. • Feedback regarding bottle-necking of assessment.	• Restructure Aims & Outcomes. • Increase from 12 to 20 credits.	IDP 303 Exploratory Project
ID305 Emerging Technology	• Module outcomes to be changed to reflect a more challenging research-based approach.	• Update syllabi. • Introduce a research-based assignment. • Increase from 12 to 20 credits. • Focus on BSc pathway only.	IDP 314 Emerging Technology
ID302, 304, 306-310 Major Project	• In response to student, staff and external examiners' comments, the project needs to be restructured. • In order to make the major project a true showcase of the students all-round design and academic ability the major project needs to be revised and re-focused.	• In response to staff experience and the comments of external examiners, the major project will be reduced from 84 to 60 credits. • The assessment of the project will be revised to ensure that all students are given clearer interim and final deadlines to work to. • A new complementary module, marketing and self-promotion, will deal with the commercial and exhibition aspects of the project.	IDP 301 Major Project. IDP 302 Marketing & Self-Promotion

Figure 6.10 Review of Phase 2 Modular Structure

6.8 Changes Implemented as a Result of the Review

As a result of the module and programme review the programme was re-structured to conform to the latest University of Wales (UoW) guidelines on modularity. Previously all modules were based upon 12 credits or multiples thereof with each one delivered within a semester. The UoW specifies modules based upon multiples of 10 credits. It is also clear from student questionnaires and staff feedback that the system of two 15-week semesters failed to deliver the optimum environment for effective Teaching, Learning and Assessment of innovation within industrial (product) design.

Essentially the changes may be summarised as structural. Changes were confined to updating the modules and grouping them into larger integrated modules of study. This allows the team delivering the module to structure the teaching, learning and assessment process to provide an enhanced educational and innovative experience for the student. The taught material is more integrated, the students have more time to assimilate and practise concepts learned and the quality of assessment is improved. To facilitate the delivery of the larger modules and to provide scope for students to exploit their innovative capacity the School of Industrial Design returned to a term-based delivery mode across all programmes. Reverting to term-based teaching should improve retention and progression by providing a more organic learning experience. The move also removes the artificial January/February break from the midpoint of the academic year. This break caused by the disruption associated with end of semester assessments and reading week resulted in problems with student retention, failure and loss of continuity in project work.

6.8.1 Revised Modular Structure

As discussed above the modular structure was completely revised. A number of supporting, non-core modules were withdrawn and replaced with additional design modules that utilised new technology in their delivery. The third year was completely re-designed. The 84-credit major project was scrapped in favour of a more focused 60-credit project. Marketing and self-promotion which had been part of the major project were extracted and clustered into a new 20-credit module. The 'Marketing and

Self-Promotion' module was developed with a new rationale to increase the entrepreneurial ambition of the graduates. The theory modules were rationalised to provide alternatives for the BSc and BA pathways and increased in credit value to provide opportunity for critical reflection and philosophical development.

6.8.2 Teaching Innovation

Team supervision of the major project underpinned by a system of pastoral tutors was retained. This allowed the individual student to seek out the specific support he/she required. The revised research-based modules in the final year involve a team of staff delivering a rolling programme of lectures that the undergraduates take as a basis for further research. The outcome is a paper written within tight academic guidelines and presented in a conference format. The 'Design Ethics' module provides students with the opportunity to develop and present a personal design manifesto. The 'Emerging Technology' module was developed to allow the student to explore the emergence and adoption of new technology and its effect on design-to-market innovation. The benefits of these modules is in the raised prominence given to research and in the greater value that each student attributes to his/her personal intellectual property.

6.8.3 Innovation Environment

The reorganisation of student and academic accommodation initiated in Phase 1 and consolidated in Phase 2 has made a major contribution to the culture of innovation. All students are now located on one floor with integrated seminar spaces and academic offices. Informal communications have improved and bonds forged between various student groups and academics. The attitude amongst the undergraduates has shifted from that of receiver to that of stakeholder. They now believe themselves to be contributing to something bigger than just their own qualification. This leads them to share information more freely with their peers and to actively support other students through the sharing of knowledge.

The impact of these changes has been reviewed continuously and reported in successive annual programme reports. Incremental changes have continued as

experience is gained and the views of graduates are considered, discussed and – where appropriate – implemented.
The results of four graduate years under the Phase 2 structure indicate strong evidence that the level of innovation has increased significantly. The increase in level 3 innovation is particularly encouraging. This indicates undergraduates are researching solutions outside the immediate realm of the problems or opportunities they are investigating.

6.9 Summary of Phase 2 Outcomes

The object of this phase was the refinement of an industrial design programme to develop the innovativeness of a body of industrial designers. The programme developed in response to the review at the end of Phase 1 and implemented in October 2000 was itself the subject of a major review in 2004. This chapter has discussed the implementation of the 2000 structure and its impact on student innovation. The chapter has considered the impact of the new structure in generating innovative outcomes. To a large extent these have been positive and qualitative studies indicate the improvement in innovation outputs is measurable and significant.

The outcomes identified from Phase 2 are:

- New pedagogy was implemented
- A new study environment created
- Intellectual Property Rights scheme implemented
- Student research strategy developed
- Communication and internal networking has improved
- Peer recognition in terms of student awards has improved
- Overall level of innovation has increased

The review of Phase 2 concluded that the modular structure had gone as far as it could in achieving the innovative outcomes desired. The necessity from this point forward was to change the emphasis from introducing innovation into a modular structure to one where a modular structure was introduced to the innovation process. A series of actions were identified. The implementation of the identified actions would constitute a third and final iteration in Phase 3. These actions were implemented from the beginning of the 2004/2005 academic year. Chapter 7 describes the implementation of the actions and evaluates the outcomes.

7 Development of Innovation Pedagogy Phase 3 (2004-2007)

"An open, well-informed mind is the best tool in the box."
(Andy Davey, 2001)

7.1 Introduction

During Phase 1 the programme team sought to create the conditions for innovation to flourish and achieved success in expanding the scope for innovation within the department. During Phase 2 the emphasis changed to the individual. The primary goals were to stimulate, incubate and nurture student innovation and create an internal momentum for continued evolution of the developed innovation culture. In Phase 3 the core aims were to build upon the structural changes implemented in the two preceding phases and develop a quantitative approach to measuring the innovativeness of undergraduate industrial design students.

7.2 Implementation of New Pedagogy

As identified in the earlier phases and the academic literature it is vital, for innovation to thrive, to encourage the integration of projects across modules and even across year groups. Innovation doesn't end with the student project itself but must extend to embrace the mode of delivery, assessment and feedback. As recorded in previous phases the challenge to an academic programme where assessments have to be set and deadlines met is how to create the time to allow for the incubation of innovative ideas. In this third iteration major structural changes were implemented to facilitate the identified requirements. The programme was de-semesterised to allow 'organic' teaching, learning and assessment strategies to be implemented. Modules were integrated to encourage the development of spontaneous interaction of the taught material and to enable structured integration of assignments.

7.3 New Modular Structure

The existing 12-credit modular structure had been in place since 1997. Successive Programme Management and Staff/Student meetings highlighted the fragmented nature of the programme structure. External Examiner reports consistently highlighted concerns of over-assessment within the programme. The portfolio team therefore decided to take the opportunity provided by the major review initiated in 2004 to embrace the findings of the literature study and implementation of phases 1 and 2 to restructure the industrial design programme. The Industrial Design team spent considerable time discussing the approach to teaching, learning and assessment. The outcome of that discussion was presented within the programme document issued in January 2005 (but implemented from September 2004).

Essentially the existing modules were grouped into larger integrated modules of study. This allowed the team delivering the module to structure the teaching, learning and assessment process to provide an enhanced educational experience for the student based upon an open approach to innovation. The taught material is more integrated, the students have more time to assimilate and practise concepts learned and the quality of assessment is improved.

Thus the programme was created to provide graduates with a breadth of industrial design opportunities fused with a degree of technological knowledge and socio-cultural sensitivity to enable them to lead the design and development of innovative products, services and systems. Students on the BSc (Hons) Industrial Design programme are directed to undertake a self-initiated major project that involves the analysis, synthesis and realisation of a novel design proposal which demonstrates sustainable decision making in relation to the technical, operational and manufacturing aspects of industrially produced products, services and systems. The student's energies were guided towards the pursuit of innovative outcomes which could be evaluated against the benchmark of the Altshuller index of innovation and the Likert scale discussed previously (chapter 4). The third iteration of the programme structure resulted in the following modular structure (Figure 7.1).

Phase 3 - BSc (Honours) Industrial/Product Design (2004 onward)		
LEVEL 1 Term 1 Term 2 Term 3	**LEVEL 2** Term 1 Term 2 Term 3	**LEVEL 3** Term 1 Term 2 Term 3
M1X5474 Design Methods 40C	M2X6500 Professional Practice 40C	M3X6520 Major Project [BSID] 60C
M1X7399 History of ID & Material Culture [incl. Marketing] 20C	M2X6501 Design in Context [incl. Research Methods] 20C	
M1X5477 Introduction to Technology 20C	M2X6502 Materials & Manufacturing Processes 20C	M3X6513 Marketing & Self Promotion 20C
M1X5472 3D Computer Aided Design 20C	M2X6504 Mechanics & Electronics 20C	M3X6514 Exploratory Project 20C
M1X7398 Ergonomics 20C	M2X6506 Advanced Solid Modelling 20C	M3X6516 Emerging Technology 20C

Innovation Centred Modules

Figure 7.1 BSc(Hons) Industrial Design Structure (Walsh & Jenkins 2005)

7.4 Innovation Mindset

"An innovation mindset is an attitude, a state of mind, which should permeate the entire institution. The hallmarks of this mindset can be seen in the way individuals at all levels in the organisation interface with each other." (Kuczmarski 1996).

Although there is no definitive study of what gives rise to an innovative mindset we can identify certain character attributes which are common in the innovative mind. From Ditkoff (2003) we get the following list of innovative traits common to all innovators:

- Balance intuition and analysis
- They challenge the status quo
- A commitment to learning
- Curiosity
- Flexible/adaptive approach
- Formally articulate
- Imaginative
- Makes new connections
- Persevering
- Playful/humorous
- Reflective
- Resilient
- Risk taker
- Self-accepting
- Self-motivated
- Situationally collaborative
- Tolerant of ambiguity
- Visionary

By understanding the characteristics of an innovative mind we can attempt to create an environment and engender a spirit whereby these characteristics are encouraged. By these means innovation is stimulated, not by artificial means or arbitrary targets but by an organic process of stimulation and incubation. By creating an organic pedagogy for the nurturing of innovative attributes we create a sustainable model. The major structural changes implemented in Phase 3 were designed to develop the traits identified by Ditkoff. In essence the modular structure was developed to provide curriculum content and a teaching, learning and assessment culture which incrementally increased the propensity of students to innovate. Three factors were referenced to benchmark the change in the innovation mindset:

- Student Research Outputs
- Generated Intellectual Property
- Peer Recognition
- Student Research Outputs

Central to the implementation of Phase 3 was the continued development of the student-centred research strategy. Phase 2 witnessed the development of a student research strategy by which second-year students were directed and encouraged to research and submit papers for international conferences. In 2004 one student presented a paper in Oslo. The scheme continued into Phase 3 with continued success. In 2005 Jonathon Henshall presented a paper at ERA 05 World Design Congress in Copenhagen. This was followed by the presentation by Level 5 (second year) students of six papers at the conference 'Crossing Boundaries' sponsored by Cumulus in Schwäbisch Gmünd, Germany.

Figure 7.2 Elly Dawson, Tyra Oseng, Rhys Thomas, Theo Bridge, Richard Crocker, Harriet Brewster and Andrew Langdon. Schwäbisch Gmünd 2007

By emphasising the value of research the team successfully introduced the notion of novelty and innovation to the development of student projects. The demands of researching and writing a paper for an external audience galvanised the students to reach higher. Students recognised the value of their generated intellectual property and were encouraged by receiving external feedback. Even though the number of student papers selected for conference was relatively modest the overall impact was seen in the improved grades and numbers of references included in student papers.

Recognition of the contribution made by the Swansea research strategy was given by Professors George Burden and Peter Stebbing in the preface to the published proceedings of the Schwäbisch Gmünd conference. "We strongly recommend that students be specifically invited to present papers in a student session at future conferences." "We would like to commend those students who contributed and presented papers at this conference." (Burden and Stebbing 2007)

7.4.1 Generated Intellectual Property

Graduates of Phase 3 continued to contribute to the success of the IPR scheme. The following graph (Figure 7.3) provided the team with the confidence to determine that there had been a significant change in the level of innovation demonstrated by the students.

There was continued high take-up of the scheme despite a small dip in 2005-6. The relevancy of the scheme rests in the impact it has on the value students place on their IPR. Patenting an idea in university is not in itself a definitive sign of innovation but it is an indication of the propensity to innovate. It is innovation propensity rather than fully realised innovation that is the object of this study.

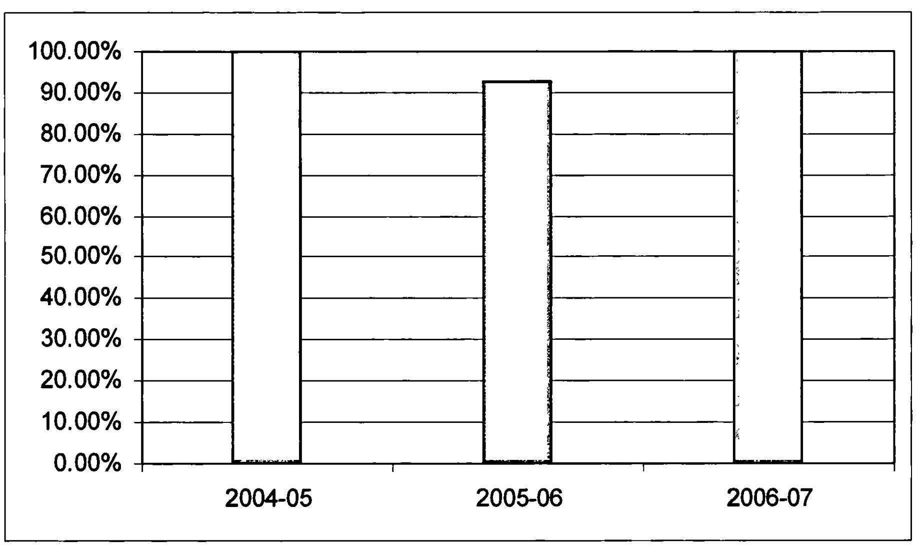


Figure 7.3 Student Patent Applications 2005-2007

Protecting student IPR is a clear statement of intent by the institution that intellectual property is taken seriously. The benefits to the student reside in the developed knowledge and understanding of the process and greater awareness of the value of the generated intellectual property (IP). The university benefits from potential income either from the projects themselves or from the commercial projects attracted to the department given the confidence industry derives from working with an institution which understands the value of IP.

7.4.2 Peer Recognition – Innovation Awards

Following the demise of the WDA Technology Awards in 2003 there were few opportunities to benchmark student progress in external competitions and awards. In 2006 and 2007 this changed with the introduction of two awards schemes. The Corus Award for Product Design and the 'Ffres' Award sponsored by Design Wales attracted submissions from all Wales' industrial design programmes. The Corus Award was won by a second-year industrial (product) design student for the design of a novel stainless steel toaster. In the 'Ffres' Awards the School of Industrial Design at Swansea Institute had two projects in the final shortlist of three and took first place at an awards ceremony at the Newport Centre in June 2007.
In addition to winning the awards a number of students were also finalists thus indicating the revised programme's ability to innovate consistently.

Luke Khan	**Winner 'Ffres' Award for Product Design**	**2007**
James Murray	**Finalist 'Ffres' Award for Product Design**	**2007**
Kevin Jones	**Winner Corus Award for Product Design**	**2007**
Mikko Illi, Craig Perriman	**Finalists Corus Award for Product Design**	**2006**

7.5 Innovation Outcomes

Throughout the three phases of the project and the Phase 0 pre-evaluation, the primary scales for measuring the level of innovativeness were the scale based upon Altshuller's work and the five-point Likert Scale developed by the programme team. By Phase 3 clear trends were emerging which indicated a change in the innovativeness of the undergraduate body. Further to these scales was the opportunity to contrast the performance of the industrial (product) design cohort against that of the automotive design programme. The data was collated (Appendix 4, p.273), the results summarised and they are displayed on the following pages. Thus far the outcomes have been evaluated qualitatively. The tables and histograms provide a useful visual indicator of the innovativeness of the projects but cannot provide an accurate value of significance.

7.5.1 Comparative Analysis of Innovation against Altshuller Scale

What emerged was a pattern whereby 70-75% of final-year student projects could be classified as level 1 and level 2 innovations. What could also be seen was that approximately 18-20% were level 3 innovations. The key figure for the academic team involved was the 5% who produced level 4 innovations according to Altshuller's criteria. For Phase 3, classification of projects on the basis of Altshuller's scale was not considered a satisfactory model for statistical analysis. The classifications were too coarse and the distribution too narrow to allow for statistically verifiable differentiation between levels.

Altshuller's Five Levels of Innovation – Phase 3					
	Level 1	Level 2	Level 3	Level 4	Level 5
Industrial	3	6	5	1	0
Auto	2	5	1	0	0
	Phase 3				
	Level 1	Level 2	Level 3	Level 4	Level 5
% ID	0.20	0.40	0.33	0.07	0.00
%Auto	0.25	0.63	0.13	0.00	0.00

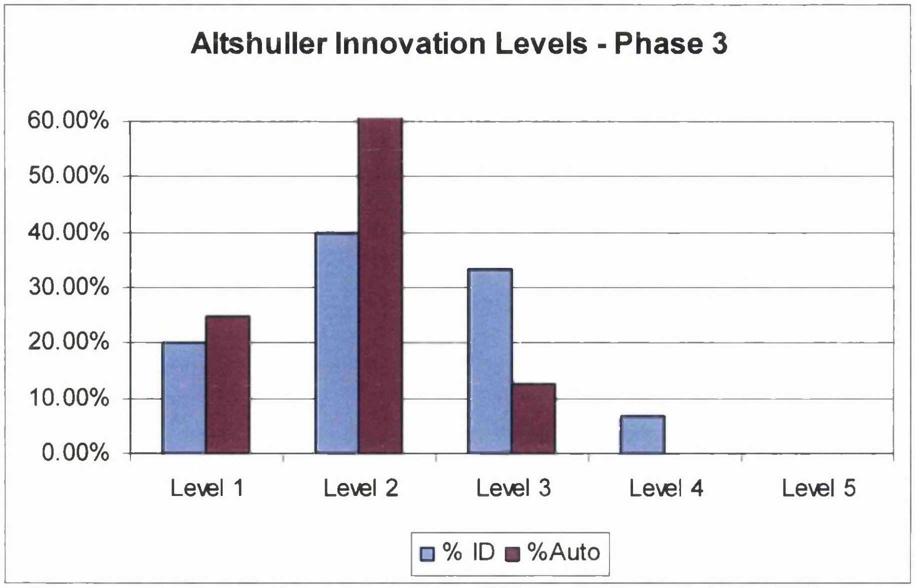


Figure 7.4 Innovation against the Altshuller Scale 2004-2007 (Phase 3)

The Altshuller scale allowed the programme team to identify trends in innovative outputs but not to the extent that those trends could be verified with any statistical accuracy.

7.5.2 Comparative Analysis of Innovation against Likert Scale

In order that the innovation outputs may be compared with quantifiable accuracy a Likert or Semantic Differential scale was proposed. The resulting Likert analysis questionnaire was used to evaluate all projects from each phase.

Phase 3					
	Level 1	Level 2	Level 3	Level 4	Level 5
Industrial	1	3	4	4	3
Auto	0	4	2	2	0
	Phase 3				
	Level 1	Level 2	Level 3	Level 4	Level 5
% ID	0.07	0.20	0.27	0.27	0.20
%Auto	0.00	0.50	0.25	0.25	0.00

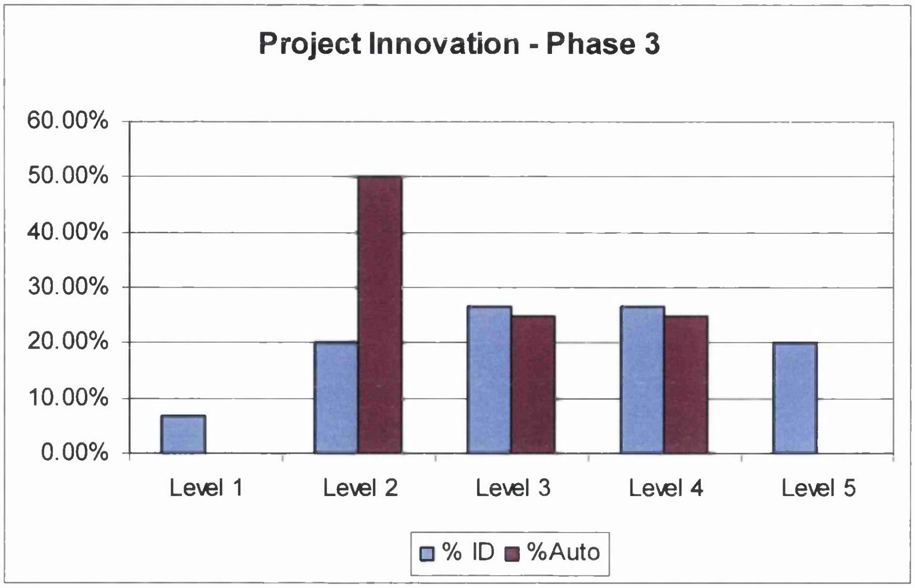


Figure 7.5 Innovation against the Likert Scale 2004-2007 (Phase 3)

A detailed comparative analysis of each phase is presented in sections 7.10 – 7.13.

7.6 Review of Pedagogy

7.6.1 Review of Modular Structure

The aim of the review was to assess the impact of the third and, in the case of this thesis, final model on the level of innovation by quantifying the impact of the pedagogical shift on the innovativeness of the student body. As previously discussed modular programmes of study can have a negative effect on innovation where the student has no clear overarching view of his/her programme of study. Modularity creates discrete independent 'ghettos' of programme elements that undermine the coherency of a programme of study. The implementation of the pedagogical model described in Phase 3 has begun to deliver the desired results. There is clear evidence from the student body in the form of student feedback questionnaires that supports the change to a term-based approach. The problem of over-assessment is overcome through a reduction of individual units of assessment and through integrated assignment planning. The revised teaching, learning and assessment strategy developed is more appropriate for determining academic progression and attainment. In terms of the innovation culture, it produces a positive effect as can be seen from the qualitative analysis of projects conducted in chapters 4 to 7 where each project was assessed against a scale based upon the work of Altshuller and a Likert scale derived from work undertaken by the OECD.

7.6.2 Support from Academics and Students

The School and Faculty possess a body of academics with a strong belief in the programme and a commitment to innovate. This commitment has been strengthened and confirmed by the introduction of the revised model in Phase 3. Also crucial to the success of the innovation project is the support of the student body. The support of the students ensured that Phase 3 produced a dynamic collaboration of ideas. Continued Faculty support was assured and resources made available to facilitate the restructuring of the programme. The support of the students became vital in Phase 3 as the emphasis of the research was transferred from the environment, culture and organisation to specific personality traits which indicate an individual's propensity to innovate. By understanding the characteristics of an innovative mind we can attempt to create an environment and engender a spirit whereby these characteristics are encouraged. By these means innovation is stimulated, not by artificial means or arbitrary targets but by an organic process of stimulation and incubation. By creating an organic pedagogy for the nurturing of innovative attributes we create a sustainable model for innovative industrial design. If there is a transferable model to be identified then the objective of innovation research must be to quantify the outcomes and identify the true statistical reliability of the data which emerges. Potentially the most important outcome of the development of the Swansea Industrial Design Model is the generated data and its analysis.

7.7 Review of Innovation Indicators

Thus far developments to the pedagogical model for innovative industrial design were measured qualitatively. Reviews were conducted and practice revised based upon interpretation by the academic team and reporting by external examiners. There was a need for a quantitative evidence-based statistical method for evaluating innovativeness. In determining the appropriate methodology for measuring innovation outcomes two main issues need to be addressed: first, the extent to which available indicators provide information on different aspects of design innovation activities; and, second, the extent to which indicators of the same activities provide similar answers. These issues can be summarised by two questions: Which indicator answers which question? Do different indicators provide the same results? Patents and innovation surveys are two ways to acquire information on the innovative activities of organisations. A wide variety of innovative activities are carried out by organisations that can be documented by innovation surveys and patent data. Some innovation inputs have been monitored for a long time, notably the resources devoted to R&D, which have been systematically measured in most advanced countries for over 40 years. However, despite its importance, R&D investment is only one source of innovation. Other innovation inputs are not yet measured, and some cannot be, (Archibugi and Pianta 1996). Innovation can be analysed, classified and measured from many perspectives. There are at least four different criteria for classifying innovation, which can be used in both patenting and innovation surveys:

- **Technology**, i.e. according to the technical characteristics of the innovation;
- **Product**, i.e. according to the nature of the product in which the innovation is likely to be embodied;
- **Sector of production**, i.e. the main economic activity of the firm that has generated the innovation;
- **Sector of use**, i.e. the main economic activity of the users of the innovation.

In the context of industrial design, innovative activities have a variety of visible outcomes. These fit into the four classifications listed above and may be product, service or process innovation. The bulk of industrial design projects are product centred. Organisations invest in technology and human resources to introduce product and process innovations into the market. Measuring the outcomes of these activities can be done by means of innovation surveys, which can account for a broad range of innovative activities, or by measuring the level of IPR generated. In order to protect their products and processes against prospective competitors, firms often apply for patents for their innovations.

Throughout the four phases (0-3) of the research two indicators were applied:

- Participation in the Intellectual Property Rights Scheme
- The Innovativeness of Design Proposals

7.8 *Participation in the Intellectual Property Rights Scheme*

As discussed in section 6.4.2 Swansea Institute's School of Industrial Design in collaboration with Swansea (now Cardiff) based Patent Attorneys Urquart Dykes and Lord submits an annual block patent application. A strong emphasis is placed on the protection of IPR and undergraduates are encouraged to register their designs and apply for patents. This has resulted in the percentage of Industrial Design students submitting patent applications rising to 100% in the 2006-2007 academic year.

The headline figure gives an impression that the level of innovation is exceptionally high amongst the Swansea graduates. However, it must be remembered that the level of scrutiny is modest compared to industrial patents. The emphasis is on the development of the student's knowledge and understanding of the IPR process. The scheme is successful in encouraging innovation on several levels: it encourages students to strive for the most innovative solution; it encourages the students to challenge received approaches to problem solving; it teaches the students to value their ideas.

The effectiveness of the scheme cannot be statistically measured due to the relatively low numbers involved. However, as the following histograms indicate, (Figure 7.6 Student Patent Submissions 1997-2007 and Figure 7.7 Student Patent Applications by Phase), a trend can be identified and a correlation made between the increasing proportion of students submitting patent applications and the phases of programme iteration.

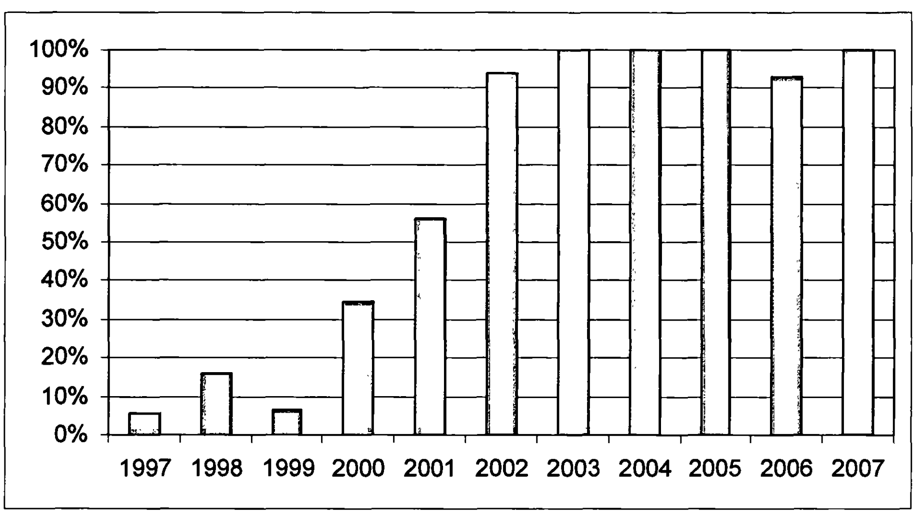


Figure 7.6 Student Patent Submissions 1997-2007

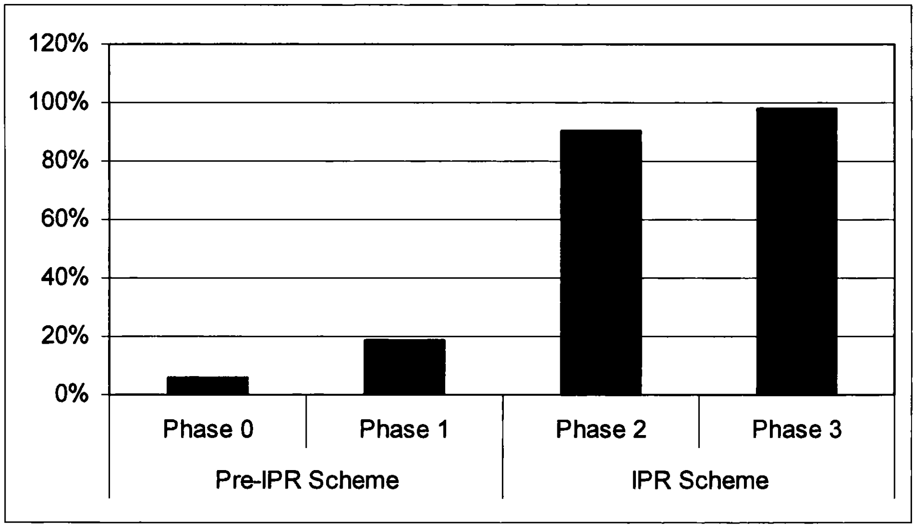


Figure 7.7 Student Patent Applications by Phase

From the evidence presented by the histograms and the reporting of external examiners the scheme can be seen to have encouraged the student body to be more aware of IPR issues, to be pro-active in seeking novel solutions to design opportunities, to be more entrepreneurial in outlook and to approach their work with far more rigour. The question of whether the IPR scheme is an indicator of innovativeness is more problematic. On the one hand it is clear that the number of instances of patent filing has increased dramatically. Yet on the other hand the IPR scheme and the relative ease of patent submission associated with it can be seen to have brought about this fact. Even without a statistical analysis it is clear that, whilst there may be a correlation between increasing student innovation and rising levels of patent submission, there is no evidence of causation. Essentially there is no evidence that rising levels of patent submission are caused by increasing levels of innovation or are simply the consequence of streamlining the IPR process for graduates. We can see therefore that student patenting as evidenced by the Institute's IPR scheme is not a useful metric for measuring student innovativeness. In essence an alternative method must be found.

7.9 *Establishing the Innovativeness of Design Proposals*

7.9.1 Innovation Survey

Innovation surveys have been developed with the specific aim of acquiring information on innovative activities carried out in organisations. Until very recently, innovation surveys were organised by government agencies, statistical offices or academic institutions for their own specific needs. In consequence, the results achieved differ significantly and are not easy to compare. Innovation surveys have also to face up to the very mixed and multi-level nature of innovations. A water purification system, a new powerboat (but also a gents urinal or a piece of furniture) might all be classified as innovations. Several attempts have been made to classify innovations according to their economic and/or technological significance. Innovations have been divided into 'improvement' versus 'basic', 'incremental' versus 'discrete', 'minor' versus 'major'. Innovation surveys have also distinguished between innovations that are new at global level and those that are new for an individual country, industry or organisation.

7.9.2 Academic Assessment of Innovation

On the face of it the most obvious measurement of innovation or innovativeness would be the projects or products of the process. In the academic world where Teaching, Learning and Assessment (TLA) are the three fundamental pillars of the educational experience, the measurement or assessment of a student's performance is regulated by the regulations of the university and Quality Assurance Agency (QAA) benchmarks. In this context the purpose of assessment is to enable students to demonstrate that they have fulfilled the objectives of the given course and for a classification of their achievement to be produced. In the assessing of student work all lecturers/examiners are expected to relate the achievements of the students to the generic educational aims and objectives of the discipline. The nature of the assessment procedure in design-based subjects is both qualitative and quantitative. In modules where the TLA approach calls for a more qualitative mode of assessment the body of work is assessed in line with the QAA benchmarks for Art & Design. In modules where the TLA approach calls for a quantitative mode of assessment then the QAA benchmarks for Engineering are applied. In certain modules where the TLA approach is drawn from both traditions then both benchmark statements are referred to. In the case of industrial design, where the final grade is derived from a combination of the major project, report, module assignments, coursework and examinations over a two-year period, the final grade does not directly correlate to the outcome of the major project. Any inference of innovativeness cannot be made from the final grade alone. An alternative methodology for determining the level of innovation of a design project is required. The methodology needs to identify the specific indicators of innovativeness evidenced by the project and a method for collating information on innovation. The approach to evaluating the innovativeness of projects extending over 12 years needs to account for the lack of availability of the original prototypes and the problems of locating graduates from earlier cohorts. Methods for gathering information on innovations are well established and documented in the literature. A method based upon the use of journals and other documents to provide information on new innovations would seem to provide the only realistic method of collating data for such an extended survey. For the purposes of this research the optimum method identified was based upon a modified version of the Literature Based Innovation Output Approach or LBIO. As discussed in chapter 4 this method allowed the team to review the outputs from each phase based upon a study of the supporting documentation produced by each project student.

7.10 Qualitative Analysis of Innovation Outcomes

7.10.1 Observations and Analysis of Project Innovation

Mapping transitions in the level of innovation demonstrated in project outcomes is at the heart of this study. Through successive phases, projects have been evaluated using a modified LBIO analysis method. The level of innovation has been evaluated against two scales – a five-point Likert scale and a five-level innovation scale derived from the work of Genrich Altshuller. Identifying the statistical significance of differences between each stage is complicated by the relatively small number of instances considered. Within the school total numbers per cohort in industrial design have varied during the course of the study from peaks of 25-30 to lows of 12-15. Consequently the analysis has been descriptive in nature and concerned with comparing mean values of project innovation levels. The following tables and histograms present a summary of the data collected. The full data set is included in Appendices 1-4 (pp.261-270).

7.10.2 Project Innovation Trends – Likert Analysis

	Level 1	Level 2	Level 3	Level 4	Level 5
Phase 0	50.98%	31.37%	11.76%	5.88%	0.00%
Phase 1	51.32%	22.37%	19.74%	5.26%	1.32%
Phase 2	22.99%	25.29%	32.18%	16.09%	3.45%
Phase 3	6.67%	20.00%	26.67%	26.67%	20.00%

Figure 7.8 Combined Likert Analysis Data

The data in
Figure 7.8 represents the outcomes of the Likert analysis by identifying the percentage of projects which fell into each level of innovation during each phase. The following graphs (Figure 7.9 and Figure 7.10) plot the changing pattern of innovation outcomes over the four phases of the research study.

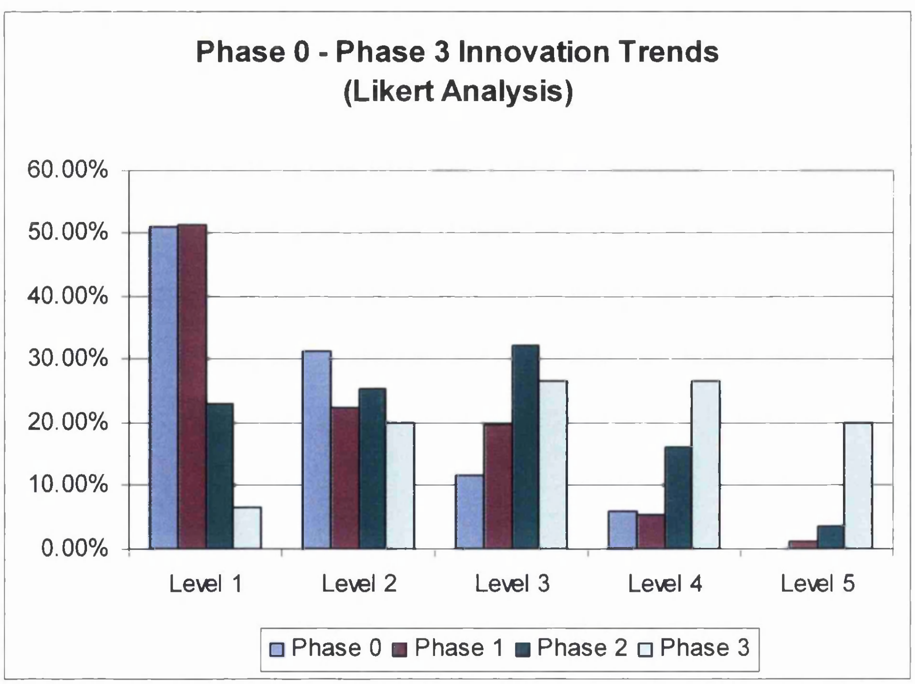


Figure 7.9 Histogram representing combined data identified by Likert analysis

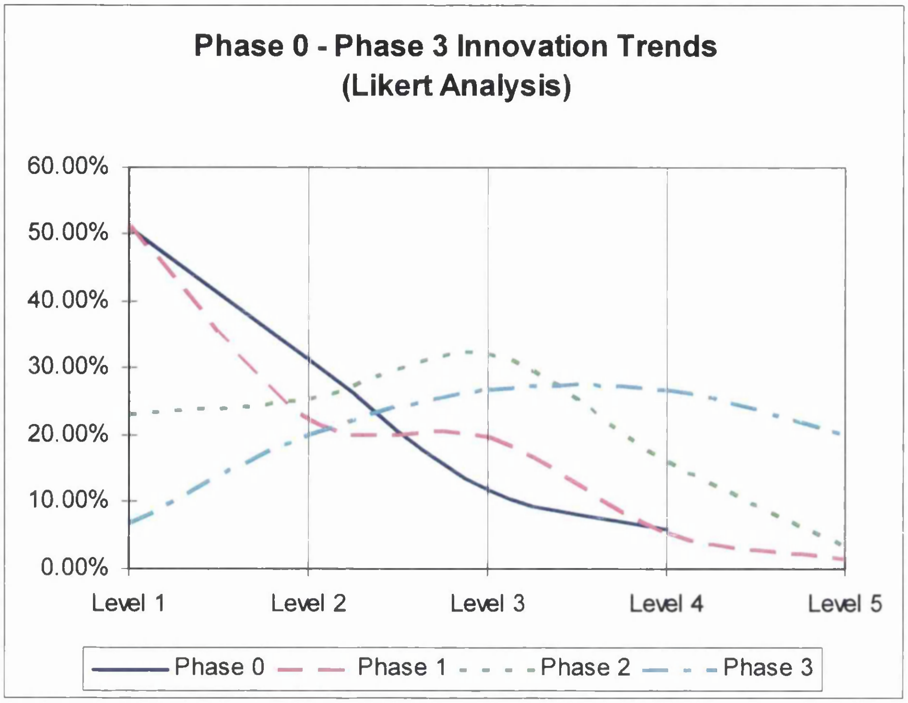


Figure 7.10 Line graph illustrating the trend in innovation levels identified by Likert analysis

The evidence of the Likert analysis of project innovation demonstrates a transition in innovation levels from a distorted J-shaped distribution, where the majority of projects are regarded as demonstrating no significant change, or change without novelty to a pattern more normally distributed where the projects tend to exhibit intermediate innovation. There is a direct correlation between the changing profile of the distribution curve and the increase in average Likert score from 1.73 in Phase 0 to 3.33 in Phase 3. The degree of shift demonstrated is indicative of changes in the innovation culture and environment within the School of Industrial Design. The nature of such changes in organisations moving from a 'foundational' to 'advanced' and onto 'Breakthrough' innovation culture was codified by Angel, Figure 2.3 Innovation Culture Continuum (Angel 2006). From the evidence of the Likert scores we may conclude that there is a degree of correlation visible in the data to support the hypothesis that the level of innovation has increased.

7.10.3 Project Innovation Trends – Altshuller Scale

	Level 1	Level 2	Level 3	Level 4	Level 5
Phase 0	62.75%	27.45%	9.80%	0.00%	0.00%
Phase 1	34.21%	44.74%	21.05%	0.00%	0.00%
Phase 2	39.08%	39.08%	19.54%	2.30%	0.00%
Phase 3	20.00%	40.00%	33.33%	6.67%	0.00%

Figure 7.11 Combined Altshuller Analysis Data

The data in
Figure 7.11 represents the outcomes of the Altshuller-based analysis by identifying the percentage of projects which fell into each level of innovation during each phase. The following graphs (Figure 7.12 and Figure 7.13) plot the changing pattern of innovation outcomes over the four phases of the research study as seen against the Altshuller index.

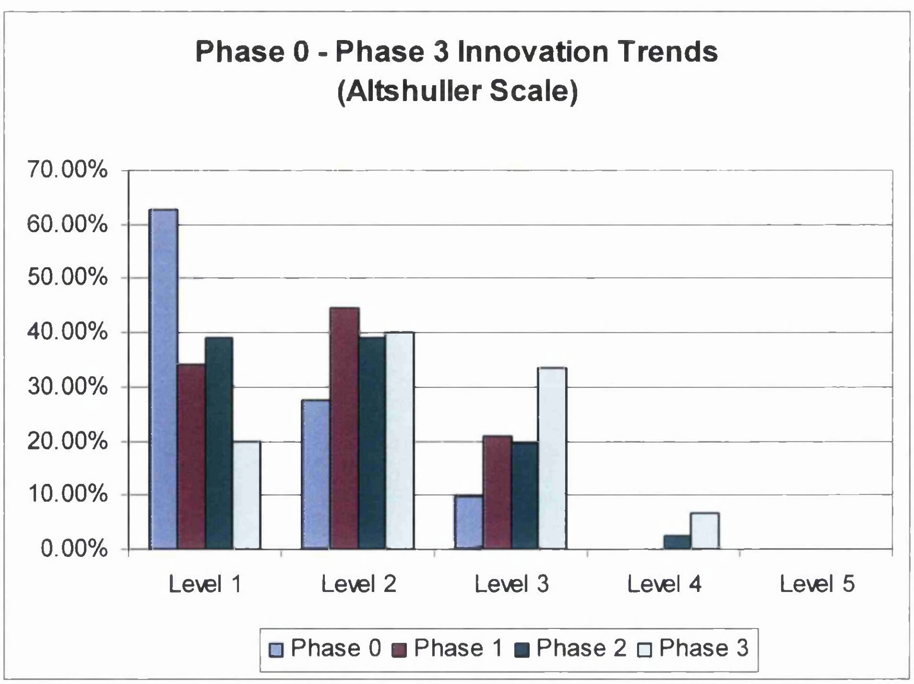


Figure 7.12 Histogram representing combined data identified by Altshuller Analysis

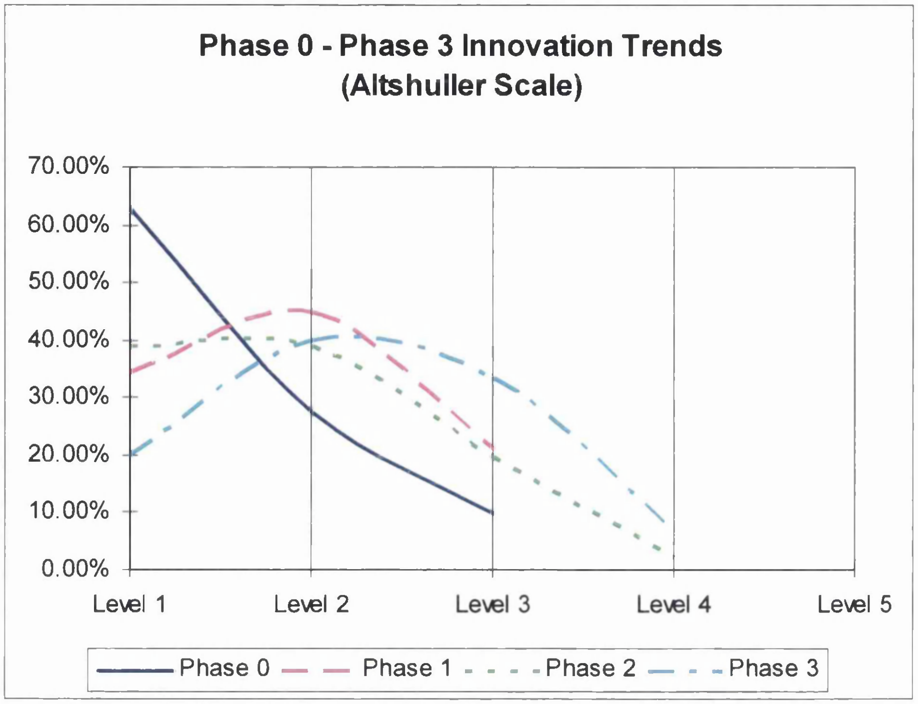


Figure 7.13 Line graph illustrating the trend in innovation levels identified by Altshuller Analysis

The Altshuller scale corroborates the findings of the Likert analysis. Though the figures present a skewed distribution it is evident from both the histogram and line graph representation of the data that innovation levels have risen over the period of the research study.

The distribution of projects against the Altshuller scale remains limited to Levels 1 to 4. The lack of Level 5 innovations creates a skewed distribution which distorts the frequency spread of the project innovations.

For the purposes of a statistically verifiable analysis the Likert data was chosen as it provides a wider distribution of values.

7.11 Quantitative Analysis of Innovation Outcomes

The project data presented in chapters 4 to 7 represents 267 projects in industrial and automotive design completed between 1995 and 2007. Initially the data was divided into four groups corresponding to Phases 0-3. The data was further sub-divided in Phases 2 and 3 into automotive design and industrial design. The data was considered with three questions in mind:

(i) How Innovative are the Industrial Design projects?
(ii) Are they more innovative than the Automotive Design projects?
(iii) Are there significant changes from one phase to another?

Both the Likert and Altshuller scales used here are examples of ordinal scales. Although they tell us that items in one category are "better" or "worse" than another they do not measure how much better or how much worse. For this reason it is more appropriate to use the median as a measure of 'typical' or average behaviour instead of the mean. In Figure 7.14 we compare the median value of the industrial design projects with that of the automotive design projects. The median gives a more satisfactory result than the mean when using an ordinal scale as it typically gives a whole number outcome which corresponds to our categories. (Of course there are instances when the median gives a result that is not a whole number: for example, suppose the calculated median is 2.5, this tells us that the midpoint of our data set lies right on the boundary between levels 2 and 3 and not that the typical value is 2.5, which does not exist as a category.)

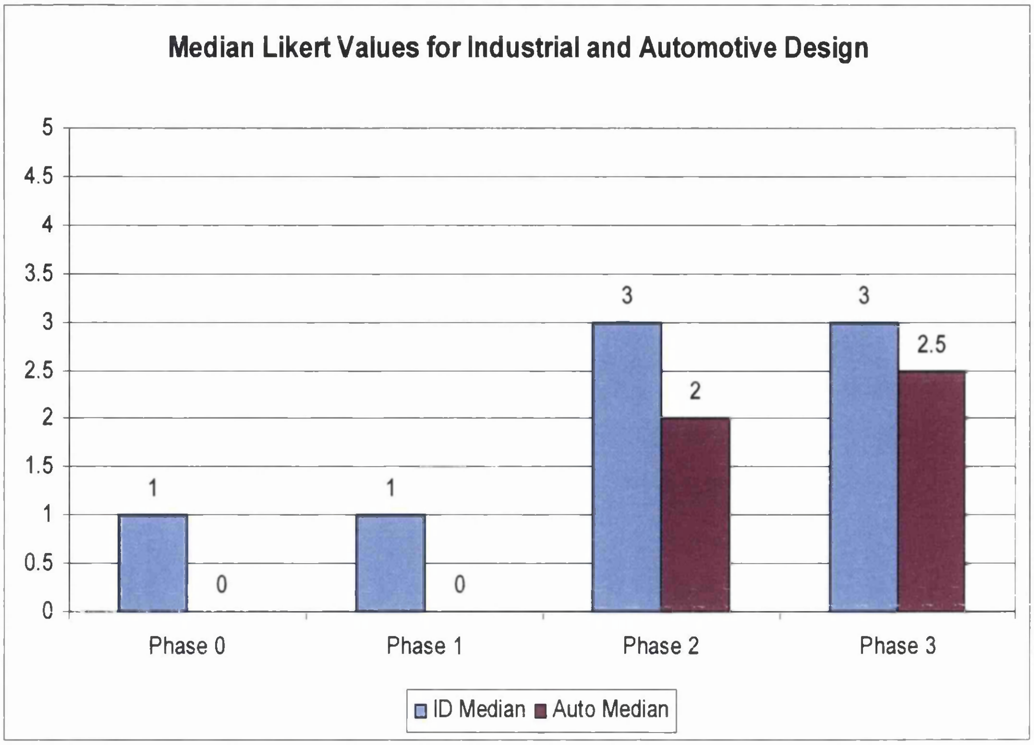


Figure 7.14 Median Likert Industrial Design scores from each phase

If we consider the median values for each phase, as identified in the Likert data, we can discern a clear change between phases. When the data relating to automotive design is added then it begins to present a picture of differing innovation levels between the programmes.

The percentages for the different phases for the **Industrial Design** Projects also show that the levels of innovation in the projects have increased as the phases have progressed.

- In Phases 0 and 1 the majority of the projects show a low level of innovations – categories 1 and 2 combined are 82% & 74% respectively, but by Phase 2 this has dropped to less than half and further reduced to 27% by Phase 3.
- Perhaps more critically is the resulting increase in the innovation that has been shown, particularly in category 5 (maximum innovation), where the percentage has risen from zero in Phase 0 to 20% by Phase 3.

Making a similar comparison between the different phases of the **Automotive Design** projects we can see that:

- In Phase 2, 71% of the projects show no innovative content (categories 1 & 2 only), whereas by phase 3 this level has dropped to 50%.
- Unfortunately, there are no projects in phase 3 that show maximum innovation (category 5), whereas 3% of the projects fall into this category in Phase 2. It is important to acknowledge that the 3% in phase 2 is actually only one project.

It is evident from the data collected from the given population that innovation has increased in Industrial Design at a steeper rate than that of Automotive Design. The question is, can these results be extended to infer what would happen if others were to participate in the different phases and would their projects reflect the same levels of innovation?

7.12 The Chi-Squared (χ^2) Test

It was over 100 years ago when K. Pearson and G.U. Yule, published their papers, Pearson (1900a) and Yule (1900), devoted to evaluating the degree of association between two qualitative variables according to their cross-classification. K. Pearson viewed qualitative categories as intervals of an underlying continuous variate and thus wanted to introduce a measure akin to his product-moment correlation coefficient between quantitative variables. G. Yule claimed that such categories as 'vaccinated/non-vaccinated' cannot be presented this way and deserve to be treated without references to the quantitative case. The chi-squared coefficient was proposed by K. Pearson as an application of his ideas for testing observed frequencies against expected values with the chi-square distribution that he invented for this purpose (Pearson 1900b). In this context, the coefficient was to be used only for testing independence in a bivariate distribution. To determine statistical significance of the observed trend in project innovation we apply the Chi-Squared (χ^2) test. The aim of the test is to demonstrate that the improvements identified in the graphs did not just happen by chance (i.e. is the change statistically significant?) and that the level of innovation in the projects is dependent on the Phase of the course in which the student was taught. In essence the Chi-Squared test indicates the significance of the degree to which the data is dependent or independent of each phase.

7.13 Implementing a Chi-Squared (χ^2) Test

7.13.1 The Null Hypothesis

From Placket (1970) we first establish a null hypothesis – variables are independent – i.e. the level of innovation is not dependent upon the phase. The null hypothesis assumes that there is no dependency of frequency of innovation on the phase of the study. We then consider the likelihood that our sample data and resulting χ^2 value could have occurred given this assumption. Using the cut-off, of significance, level of ≥ 0.05 we identify the threshold, or criterion, value of χ^2 at this level of significance. This is the threshold which our obtained value must equal or exceed to be deemed statistically significant.

7.13.2 Collating the Data

We collate and summarise the data in a two-way table. We then calculate the expected cell count (row total x column total)/grand total. The expected value gives us the number of projects that would fall into each category if the innovation were indeed independent of phase.

	Likert Scale					
	Industrial Design					
	Non Innovation		Innovation			
	No Significant Change	Change Without Novelty	Minimum Innovation	Intermediate Innovation	Maximum Innovation	
	1	2	3	4	5	marginal row totals
	Observed Values (*O*)					
Phase 0	26	16	6	3	0	*51*
Phase 1	39	17	15	4	1	*76*
Phase 2	20	22	28	14	3	*87*
Phase 3	1	3	4	4	3	*15*
marginal column totals	*86*	*58*	*53*	*25*	*7*	*229*
	Expected Frequencies (E)					
Phase 0	19	13	12	6	2	*51*
Phase 1	29	19	18	8	2	*76*
Phase 2	33	22	20	9	3	*87*
Phase 3	6	4	3	2	0	*15*
marginal column totals	*86*	*58*	*53*	*25*	*7*	*229*

Figure 7.15 The Relative Frequency Table of Observed and Expected Frequencies by Innovation Levels

Having conducted the initial analysis and checked the outcomes to ensure each expected cell count was ≥ 5 we see that all level 5 innovations and most of those in Phase 3 produce values of less than 5. Consequently the values provide inconclusive results since the only real assumption underlying the use of the Chi-Squared (other than that the sample should be random) is that no more than one-fifth of expected frequencies should be less than 5. The reason for this is that the Chi-Squared inherently tests the underlying probabilities in each cell and when the expected cell frequencies fall below 5 those probabilities cannot be estimated with enough precision. This would normally lead us to reject the null hypothesis and conclude variables are dependent, i.e. the likelihood of it happening by chance is very small. Then we can ignore the first assumption, that innovation is independent of phase, and go with the only alternative that they must be dependent upon each other.

Looking closely at the data it is clear that the low expected values are being influenced by the small amount of data available in Phase 3. The test was repeated without Phase 3, but still a number of the expected values were less than 5. One way to get around this is to group the categories, so we now consider Industrial Design projects by splitting them into the following two categories only:-

1. Non-innovation (previous categories 1 & 2)
2. Innovation (categories 3,4 & 5)

We then recalculate the expected frequencies based upon a consolidated table of observed data. All expected values were above 5 (Figure 7.16) and therefore allow the data to be used to conduct a Chi-Squared test.

	Likert Scale					
	Industrial Design					
	Non Innovation		Innovation			
	No Significant Change	Change Without Novelty	Minimum Innovation	Intermediate Innovation	Maximum Innovation	
	1	2	3	4	5	marginal row totals
	Observed Values (*O*)					
Phase 0	42		9			*51*
Phase 1	56		20			*76*
Phase 2	42		45			*87*
Phase 3	4		11			*15*
marginal column totals	*144*		*85*			*229*
	Expected Frequencies (E)					
Phase 0	32		19			*51*
Phase 1	48		28			*76*
Phase 2	55		32			*87*
Phase 3	9		6			*15*
marginal column totals	*144*		*85*			*229*

Figure 7.16 The Relative Frequency Table of Observed and Expected Frequencies by Consolidated Levels

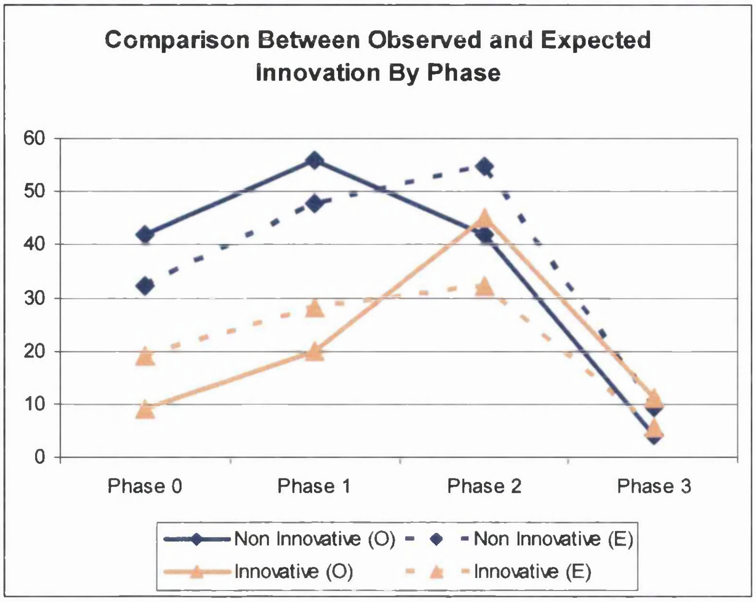


Figure 7.17 Observed Versus Expected Frequencies

7.13.3 Calculation of χ^2

We now have a data set to test our null hypothesis. The Chi-Squared test allows us to establish the statistical significance of the relationships between innovation level and phase. Using the following formula we now establish the relationship between the observed and expected frequency of occurrence.

$$\chi^2 = \sum (Observed - Expected)^2 / Expected$$

$$\chi^2 = \sum (O - E)^2 / E$$

$$\chi^2 = \sum ((42-32)^2)/32 + ((56-48)^2)/48 + ((42-55)^2)/55 + ((4-9)^2)/9 + ((9-19)^2)/19 + ((20-28)^2)/28 + ((45-32)^2)/32 + ((11-6)^2)/6$$

$$\chi^2 = \mathbf{28.46425}$$

Figure 7.18 Chi-Squared Analysis of Statistical Significance

At this point we introduce the term 'degrees of freedom' (df). In the case of χ^2, df uses the number of rows and columns in the data table to give an indication of its size.

Thus the degree of freedom is calculated as follows:

$$df = (r - 1)(c - 1)$$

where r is the number of rows and c the number of columns of data.

Test Statistic = 28.46

Number of degrees of freedom = 3

Tabulated χ^2 with three degrees of freedom = 2.9E-06

Figure 7.19 Degrees of Freedom for Chi-Squared Test

7.13.4 Evaluation

We now consider our final tabulated outcome to determine its statistical significance. Our null hypothesis assumed that there was no dependency of frequency to the phase of development. We would therefore require a figure ≥ 0.05 to confirm that hypothesis. Given that the chi-squared result with three degrees of freedom is 2.9E-06 our hypothesis is not valid. The test does, in fact, reveal with statistical significance that the level of innovation ***is*** dependent on the phase, given that there is so little evidence for difference or independence. With such a small value we can determine that the relationship is statistically significant.

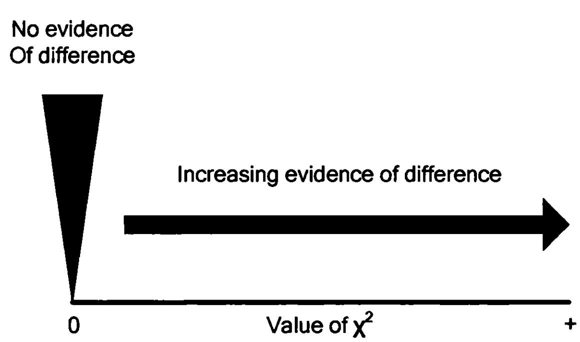


Figure 7.20 Value of χ^2 and strength of evidence

Note

The Chi-Squared test was also carried out on the Automotive Design data but, whether we considered the data in the original five categories or as the two above, there was insufficient data to run a valid test.

7.14 Defining a Pedagogy for Innovation

With confirmation that the level of innovation is dependent on the phase of programme studied, the author proposes a pedagogical approach for developing industrial design innovation based upon the following five steps. The five steps form part of an integrated programme of study where the necessary creative and technical skills are developed simultaneously. It must be remembered that the programme aims to advance scholarship and enhance intellectual abilities such as reflective and analytical thinking in the field of innovation and industrial design, thereby enabling the graduate to fully develop his/her professional standing, according to the precepts of industrial/product design as defined by the International Council of Societies of Industrial Design.

This aim is achieved by:

1. Establishing ***positive attitudes*** towards the promotion of open innovation where change, new ideas and interaction are encouraged. A culture that respects risk-takers and offers recognition to innovators. (Stoner, Gilbert & Freeman, 1995).

2. Embedding ***innovation theory*** into the curricula and encouraging the generation of IPR and research publications. (Walsh & Jenkins, 2005).

3. Building a ***task culture*** where the academic, professional and student body work towards shared goals and where a relaxed, informal attitude permeates the department. (Handy, 1993).

4. Designating an innovation coordinator to act as ***gatekeeper*** to facilitate the smooth transfer and dissemination of knowledge. (Huang & Lin, 2006).

5. Adopting an innovation friendly design process that provides a mechanism for reflective engagement in the innovation process. (Jones 1992)

Vitality and creativity must be central to the designer's understanding of innovation. Designers must be able to analyse critically the relationship between creativity and innovation in design practice. They must understand the principles of creative practice in the development of innovative solutions to given opportunities. Successful industrial design students must demonstrate proficiency in developing creative practice in response to given briefs. The principles of innovation are essential to the successful generation and exploitation of ideas for wealth creation and the student must produce evidence of professional practice that integrates the principles of innovation with his or her own professional practice.

7.15 Summary of Phase 3 Outcomes

The object of this phase was the implementation of a radical new pedagogy for the teaching, learning and assessment of industrial design with a view to increasing the level of innovation exhibited in the project and greater innovativeness on the part of the students. The programme developed in response to the review at the end of Phase 2 represented a sea change in the pedagogical strategy of the School of Industrial Design. This chapter has discussed the implementation of the 2004 structure and its impact on student innovation. The chapter has considered the success of the new pedagogy in generating innovative outcomes and an innovative culture.

The outcomes identified from Phase 3 are:

- Introduction of pedagogy for incremental development of a student's innovation propensity.
- Level of project innovation has been proven to have increased significantly with each phase of the research.
- Peer recognition in terms of student awards has continued.
- Engagement in the Intellectual Property Scheme has continued.
- A five-point pedagogical model has been developed for the development of innovation in industrial design.

The conclusion of Phase 3 brings to an end the observation of project outcomes and their associated statistical analysis using the Chi-Squared test. The phase has seen the implementation of a new industrial design innovation pedagogy and the grading of project outcomes against two scales to determine level of innovation.

Recommendations for the implementation of a five-point novel pedagogy for innovation in industrial design have been forwarded.

Three key questions remain unanswered:

1. Can the effect of the programme of study on the individual's propensity to innovate be quantified?
2. What is the effect on the individual of studying under the industrial design innovation model presented here compared with students studying on a more traditional design programme?
3. To what extent does a graduate from the industrial design programme demonstrate a propensity for innovation compared to graduates from other programmes and known innovators?

Chapter 8 describes the development, implementation and analysis of a psychometric test for innovation propensity in industrial design.

8 Measuring the Propensity for Innovation

"The fundamental purpose of design is to either answer or formulate essential questions."

(Harri Koskinen, 2001)

8.1 Introduction

Thus far the methods adopted to validate the developments in innovation pedagogy have been limited to the project outcomes. There has been discussion on the development of innovativeness and innovative traits but no evidence, other than anecdotal, has been presented which quantifies these personality attributes. The connection of innovativeness to personality has long been identified. Personal characteristics of the innovator have been identified by (for example) Veblen (1912), Robertson and Kennedy (1968), Everett Rogers (1962), Farr and Ford (1990) and Ditkoff (2003). Others have sought to identify the personality traits which mark out the characteristics of consumers of innovation: Raju (1980), Baumgartner and Steenkamp (1996), and Goldsmith and Hofacker (1991). Identifying these traits is also established within the context of marketing and new product adoption with numerous examples in the literature of innovation adoption surveys, (for example) Leavitt and Walton (1975), Kirton (1976), and Hurt, Joseph, and Cook (1977). Despite the depth and extensive range of work conducted in the field of innovation diffusion there is little evidence in the established literature of the application of psychometric evaluation to identify potential innovators in industrial design. The object of this chapter is to examine the development of a psychometric test for the identification and evaluation of specific personality traits which taken together point to the individual's propensity towards innovative behaviour. Figure 8.1 outlines the methodology followed to define the measurement tool for innovation propensity.

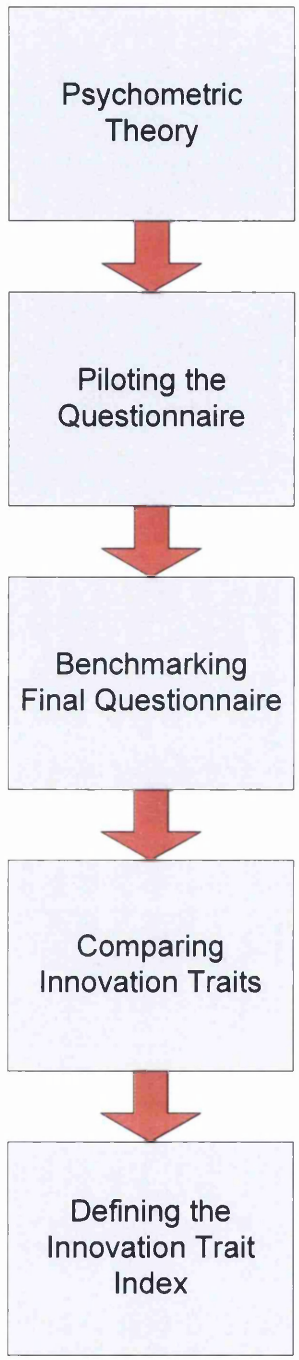


Figure 8.1 Development Methodology for Innovation Testing

8.2 *Psychometric Evaluation Methodology*

8.2.1 Origins of Psychometrics

Psychometry or psychometrics is concerned with studying the theory and technique of psychological measurement. The discipline includes the measurement of knowledge, abilities, attitudes and (crucially) personality traits. It is primarily concerned with the study of difference between individuals and between groups of individuals. It involves two major research tasks:

- The construction of instruments and procedures for measurement
- The development of theoretical approaches to measurement

With its origins firmly rooted in the work of Francis Galton psychometrics is regarded as being primarily about intelligence and mental faculties (Galton 1883). The science also has strong connections to the related field of psychophysics. Early psychometric pioneer Charles Spearman, who developed approaches to the measurement of intelligence (Spearman 1907) studied under Wilhelm Wundt and was trained in psychophysics. Psychometrician L. L. Thurstone developed and applied a theoretical approach to the measurement of psychological values referred to as the law of comparative judgment (Thurston 1927).

In more recent times psychometric theory has been applied in the measurement of personality, attitudes, academic achievement and in health-related fields. Measurement of these unobservable phenomena is difficult and much of the research and accumulated body of knowledge in this discipline have been developed in an attempt to properly define and quantify such phenomena. The definition of measurement in the social sciences has a long history. A currently widespread definition, proposed by Stanley Smith Stevens (1946), is that measurement is "the assignment of numerals to objects or events according to some rule".

The main research task is generally considered to be the discovery of associations between scores, and the factors which underlie such associations. Another major focus in psychometrics has been on personality testing. There has been a range of theoretical approaches to conceptualising and measuring personality. Some of the better-known instruments include Cattell 16PF, the Minnesota Multiphasic Personality Inventory, the Five-factor Model (or 'Big 5') and the Myers-Briggs Type Indicator. Attitudes have also been studied extensively in psychometrics. A common approach to the measurement of attitudes is the use of the Likert scale. An alternative approach involves the application of unfolding measurement models, the most general being the Hyperbolic Cosine Model (Andrich & Luo, 1993).

8.2.2 Reliability and Validity

The key traditional concepts in classical test theory are reliability and validity. A reliable measure is measuring something consistently, while a valid measure is measuring what it is supposed to measure. A reliable measure may be consistent without necessarily being valid, e.g. a measurement instrument like a broken ruler may always under-measure a quantity by the same amount each time (consistently), but the resulting quantity is still wrong, i.e. invalid. Both reliability and validity may be assessed mathematically. Internal consistency may be assessed by correlating performance on two halves of a test (split-half reliability); the value of the Pearson product-moment correlation coefficient is adjusted with the Spearman-Brown prediction formula to correspond to the correlation between two full-length tests.

A commonly used measure is Cronbach's α, which is equivalent to the mean of all possible split-half coefficients, (Cronbach 1951). Stability over repeated measures is assessed with the Pearson coefficient, as is the equivalence of different versions of the same measure (different forms of an intelligence test, for example).

Validity may be assessed by correlating measures with a criterion measure known to be valid. That is so say the data under evaluation can be 'benchmarked' against existing data known to exhibit the required criteria. When the criterion measure is collected at the same time as the measure being validated the goal is to establish concurrent validity; when the criterion is collected later the goal is to establish predictive validity. A measure has construct validity if it is related to other variables as required by theory. Content validity is simply a demonstration that the items of a test are drawn from the domain being measured. In a personnel selection example, test content is based on a defined statement or set of statements of knowledge, skill, ability, or other characteristics obtained from a job analysis. In this case the test content is derived from an evaluation of innovation traits common to proven innovators. In this study the aim is to establish predictive validity of innovativeness. Hurt et al (1977) define innovativeness as "a normally distributed underlying personality construct, which may be interpreted as a willingness to change". The inventory for the measurement of innovativeness was based on evidence that innovativeness is a normally distributed, unidimensional characteristic of the individuals who compose a social system (Rogers and Shoemaker, 1971).

8.3 Industrial Design Innovation Trait Inventory

8.3.1 Characteristic Traits of Innovativeness

From the established literature there is a wealth of references to the personality traits common to known innovators. From Ditkoff (2003) we get the following list of innovative traits (2.4.3 Individual Characteristics of an Innovative Mindset):

- Balance intuition and analysis
- They challenge the status quo
- A commitment to learning
- Curiosity
- Flexible/adaptive approach
- Formally articulate
- Imaginative
- Makes new connections
- Persevering
- Playful/humorous
- Reflective
- Resilient
- Risk taker
- Self-accepting
- Self-motivated
- Situationally collaborative
- Tolerant of ambiguity
- Visionary

To gather comprehensive data for each of the 20 traits from a sufficient population group would prove a gargantuan undertaking. The author reduced the list to ten traits by eliminating traits which were common to graduate level subjects such as 'formally articulate' and 'reflective', and by combining traits which could be seen as very similar from a test perspective (Figure 8.2).

Ditkoff's 20 Characteristics	**Reduced list of 10 Traits**
Committed to learning	Eliminated as characteristics common to all graduates
Formally articulate	
Reflective	
Resilient	Ambitious
Persevering	
Self-accepting	Confidence
Balances intuition & analysis	
Tolerates ambiguity	Easy going
Challenges status quo	Forward looking
Curious	
Situationally collaborative	Good team player
Playful/humorous	Humour
Visionary	Imaginative
Entertains the fantastic	
Makes new connections	Laterality/Perceptive
Recognizes patterns	
Self-motivated	Likely to be a success
Peripatetic	
Flexible/adaptive	
Takes risks	Risk taker

Figure 8.2 Reduced List of 10 Traits of Innovativeness

This reduced list was considered but the complexity and size of the inventory was too great. The author assembled an expert panel to consider the ten characteristics with a view to reducing their number.

8.3.2 Expert Panel

The Expert Panel comprised five members, each of which had many years' experience working in innovation led businesses or organisations. The threshold for inclusion on the panel was that each member had to demonstrate one or more of the following:

- Ten or more years in R&D led business
- Ten or more years in innovation led teaching or research
- A significant publishing record in the field of innovation theory

8.3.3 Building the Trait Inventory

Selection of the final list of innovation attributes was conducted in three stages. Firstly, the panel were asked to weight each of the attributes in order of importance with respect to each stage of the design innovation process. Secondly, the panel were asked to score each attribute on a five-point scale for each stage of the design process. These were combined to give an average score for each attribute. Finally, the attribute score was weighted to give a final score which was tabulated to provide a final weighted list of the most important personality traits.

8.3.4 Developing Attribute Weightings

Each attribute was weighted on a scale of 1-10 with 1 being the most important and 10 the least. Thus, the lower the score the more important the attribute.

		Identification	**Conceptualisation**	**Realisation**	**Implementation**	**Score**	**Ranking**
			Expert A				
1	Ambitious	2	2	2	3	9	**9**
2	Confidence	5	6	10	9	30	**2**
3	Easygoing	3	3	3	2	11	**8**
4	Forward looking	8	8	5	7	28	**5**
5	Good team player	1	1	1	4	7	**10**
6	Humour	4	4	6	1	15	**7**
7	Imaginative	9	10	4	5	28	**5**
8	Laterality/Perceptive	10	9	8	6	33	**1**
9	Likely to be a success	7	5	9	8	29	**4**
10	Risk taker	6	7	7	10	30	**2**

Figure 8.3 Weighting of characteristics – Expert A

Expert B							
1	Ambitious	1	2	4	4	11	**9**
2	Confidence	5	6	9	9	29	**2**
3	Easygoing	7	7	6	6	26	**4**
4	Forward looking	8	8	2	1	19	**7**
5	Good team player	2	1	3	5	11	**9**
6	Humour	6	4	1	2	13	**8**
7	Imaginative	9	9	7	3	28	**3**
8	Laterality/Perceptive	10	10	5	8	33	**1**
9	Likely to be a success	3	3	10	10	26	**4**
10	Risk taker	4	5	8	7	24	**6**

Figure 8.4 Weighting of characteristics – Expert B

Expert C							
1	Ambitious	2	5	8	4	19	**7**
2	Confidence	8	8	9	9	34	**2**
3	Easygoing	4	1	1	3	9	**10**
4	Forward looking	7	10	7	5	29	**3**
5	Good team player	5	4	4	8	21	**6**
6	Humour	3	3	2	2	10	**9**
7	Imaginative	10	7	6	1	24	**5**
8	Laterality/Perceptive	9	6	5	7	27	**4**
9	Likely to be a success	6	9	10	10	35	**1**
10	Risk taker	1	2	3	6	12	**8**

Figure 8.5 Weighting of characteristics – Expert C

Expert D							
1	Ambitious	2	4	6	7	19	**6**
2	Confidence	5	6	10	10	31	**3**
3	Easygoing	4	3	1	2	10	**9**
4	Forward looking	9	10	8	8	35	**1**
5	Good team player	3	5	4	4	16	**8**
6	Humour	1	2	2	1	6	**10**
7	Imaginative	10	9	5	3	27	**4**
8	Laterality/Perceptive	8	1	3	5	17	**7**
9	Likely to be a success	6	8	9	9	32	**2**
10	Risk taker	7	7	7	6	27	**4**

Figure 8.6 Weighting of characteristics – Expert D

Expert E							
1	Ambitious	5	4	9	9	27	**3**
2	Confidence	6	8	10	10	34	**1**
3	Easygoing	4	3	8	2	17	**8**
4	Forward looking	2	7	5	6	20	**7**
5	Good team player	1	1	1	1	4	**10**
6	Humour	8	9	2	3	22	**6**
7	Imaginative	7	10	4	4	25	**5**
8	Laterality/Perceptive	10	5	7	5	27	**3**
9	Likely to be a success	9	6	6	8	29	**2**
10	Risk taker	3	2	3	7	15	**9**

Figure 8. 7 Weighting of characteristics – Expert E

		A	**B**	**C**	**D**	**E**	**Final Score**
1	Ambitious	9	9	7	6	3	**34**
2	Confidence	2	2	2	3	1	**10**
3	Easygoing	8	4	10	9	8	**39**
4	Forward looking	5	7	3	1	7	**23**
5	Good team player	10	9	6	8	10	**43**
6	Humour	7	8	9	10	6	**40**
7	Imaginative	5	3	5	4	5	**22**
8	Laterality/Perceptive	1	1	4	7	3	**16**
9	Likely to be a success	4	4	1	2	2	**13**
10	Risk taker	2	6	8	4	9	**29**

Figure 8.8 Combined Weightings

	Final Score	**Rank Weighting**
Ambitious	34	4
Confidence	10	10
Easygoing	39	3
Forward looking	23	6
Good team player	43	1
Humour	40	2
Imaginative	22	7
Laterality/Perceptive	16	8
Likely to be a success	13	9
Risk taker	29	5

Figure 8.9 Weightings Devised by Expert Panel

8.3.5 Developing Attribute Scores

The weightings having been defined the evaluation was repeated using a five-point Likert scale to score each attribute in the industrial design innovation cycle.

		Identification	Conceptualisation	Realisation	Implementation	Trait Score
Expert A						
1	Ambitious	2	2	3	5	12
2	Confidence	3	5	5	5	18
3	Easygoing	3	4	4	3	14
4	Forward looking	4	5	3	3	15
5	Good team player	1	3	4	4	12
6	Humour	3	4	2	2	11
7	Imaginative	4	5	4	3	16
8	Laterality/Perceptive	5	5	4	3	17
9	Likely to be a success	3	5	5	5	18
10	Risk taker	3	5	4	5	17

Figure 8.10 Scoring of characteristics – Expert A

Expert B						
1	Ambitious	2	2	3	4	11
2	Confidence	2	2	3	5	12
3	Easygoing	3	3	4	4	14
4	Forward looking	3	4	1	1	9
5	Good team player	1	2	3	4	10
6	Humour	3	3	2	1	9
7	Imaginative	4	4	2	3	13
8	Laterality/Perceptive	5	5	3	3	16
9	Likely to be a success	2	3	3	5	13
10	Risk taker	2	2	3	5	12

Figure 8.11 Scoring of characteristics – Expert B

Expert C						
1	Ambitious	3	4	5	5	17
2	Confidence	5	4	4	5	18
3	Easygoing	4	3	3	3	13
4	Forward looking	5	5	3	5	18
5	Good team player	2	5	4	5	16
6	Humour	5	4	4	4	17
7	Imaginative	5	5	5	5	20
8	Laterality/Perceptive	5	5	4	5	19
9	Likely to be a success	3	5	4	5	17
10	Risk taker	2	4	5	5	16

Figure 8.12 Scoring of characteristics – Expert C

Expert D						
1	Ambitious	4	5	5	5	19
2	Confidence	3	4	5	5	17
3	Easygoing	5	5	5	5	20
4	Forward looking	4	5	3	5	17
5	Good team player	4	5	4	5	18
6	Humour	5	5	3	3	16
7	Imaginative	5	5	3	4	17
8	Laterality/Perceptive	5	5	4	5	19
9	Likely to be a success	3	4	5	5	17
10	Risk taker	2	4	5	5	16

Figure 8.13 Scoring of characteristics – Expert D

Expert E						
1	Ambitious	3	4	3	5	15
2	Confidence	2	4	5	5	16
3	Easygoing	2	3	4	3	12
4	Forward looking	3	5	4	2	14
5	Good team player	1	2	3	3	9
6	Humour	5	3	2	4	14
7	Imaginative	3	5	3	3	14
8	Laterality/Perceptive	5	5	4	5	19
9	Likely to be a success	5	4	5	5	19
10	Risk taker	2	4	3	4	13

Figure 8.14 Scoring of characteristics – Expert E

		A	B	C	D	E	Aggregate Score
1	Ambitious	12	11	17	19	15	**74**
2	Confidence	18	12	18	17	16	**81**
3	Easygoing	14	14	13	20	12	**73**
4	Forward looking	15	9	18	17	14	**73**
5	Good team player	12	10	16	18	9	**65**
6	Humour	11	9	17	16	14	**67**
7	Imaginative	16	13	20	17	14	**80**
8	Laterality/Perceptive	17	16	19	19	19	**90**
9	Likely to be a success	18	13	17	17	19	**84**
10	Risk taker	17	12	16	16	13	**74**

Figure 8.15 Table of scores generated by Likert Analysis of each Trait

8.3.6 Defining the Final Innovation Trait Inventory

The final list of attributes was defined by multiplying the aggregate score for each attribute by the weighting factor. This gave a final score which could then be ranked.

	Aggregate Score	Rank Weighting	Final Sore	Final Rank
Ambitious	74	4	296	7
Confidence	**81**	**10**	**810**	**1**
Easygoing	73	3	219	8
Forward looking	**73**	**6**	**438**	**5**
Good team player	65	1	65	10
Humour	67	2	134	9
Imaginative	**80**	**7**	**560**	**4**
Laterality/Perceptive	**90**	**8**	**720**	**3**
Likely to be a success	**84**	**9**	**756**	**2**
Risk taker	**74**	**5**	**370**	**6**

Figure 8.16 Application of Weighting Factor to Likert Score to give a final score for each attribute.

The author proposes six innovative traits based upon the work of the expert panel combined with a review of the literature. These can be summarised as:

- Forward looking
- Likelihood of being successful
- Capacity for imaginative thinking
- Capacity for risk taking
- Self-confidence
- Laterality

Forward Looking

A forward-looking attitude is an essential trait of any innovator. In contemporary society individuals can either be overwhelmed by change or actively embrace and seek change. It is the change accepting and seeking attitude that is identified here. Such an individual challenges the status quo and conventions.

Likelihood of Being Successful

Innovators are driven individuals who demonstrate persistence, resilience, self-motivation and sheer hard work. In the context of innovation the importance of individual determination to succeed cannot be over-stated.

Capacity for Imaginative Thinking

Imagination and creativity are linked in this trait which recognises the characteristics of playfulness, imagination, dreaming and day-dreaming – what Ditkoff calls 'entertaining the fantastic'. The capacity for imagination in the innovative mindset is recognised by the literature in many forms. Imagination and creative thinking is a facet of the professions and results in the generation of new ideas and in the building of innovation capacity.

Capacity for Risk Taking

We live in a risk-adverse society where the emphasis is on security in decision-making and the avoidance of failure rather than risk and challenging the established conventions. Innovators need to be tolerant of ambiguity and accepting of failure in the pursuit of the new.

Self-confidence

This final trait is not to be confused with over-confidence or arrogance, though they can sometimes be portrayed as such. Self-confidence in an innovator is self-assurance, self-acceptance and self-belief. Too often would-be innovators are deterred by a lack of self-belief or distracted by the need to be liked or accepted by others. The self-confident individual accepts their strengths and weaknesses without the need to 'look good' in others' eyes.

Laterality

Laterality refers to the relative dominance of one side of the brain over the other. Work by Roger Sperry in the 1960s demonstrated that each of the two hemispheres in the brain is configured to conduct specialist functions and has its own independent sensations, perceptions, ideas and thoughts, all separate from the opposite hemisphere (Sperry 1966). For most individuals the left hemisphere is analytical and performs functions in a sequential and logical fashion. This is the side which controls language, academic studies and rationality. The right hemisphere is creative and intuitive and is the domain of ideas, of art and music. Individuals with no hemispherical dominance, i.e. a balanced brain, find themselves in the position of being able to balance both the rational and artistic temperaments without being dominated by either. The inclusion of a test to determine the left/right dominance enables us to determine the importance of hemisphere dominance in the innovative mindset. Tension between left/right dominance has been discussed in 3.4.2 and 3.4.6.

8.4 Constructing the Psychometric Test

8.4.1 Personality Factors

Typically psychometric tests are aimed at identifying general personality types. The most widely used tests are those based on the work of R.B. Cattell. Cattell has been, without question, one of the most influential psychologists in the world. Since much of his work has been concerned with the factor analysis of personality, his findings must be scrutinised with the utmost care. The most important reference is Cattell (1981) which describes his empirical work and theory. Cattell defines 16 personality factors to account for much of the variance among personality traits among adults (Cattell, Eber and Tatsuoko 1970). These factors can be described as bipolar in nature and are summarised as:

A - Warmth (Reserved vs. Warm)
B - Reasoning (Concrete vs. Abstract)
C - Emotional Stability (Reactive vs. Emotionally Stable)
D - Dominance (Deferential vs. Dominant)
E - Liveliness (Serious vs. Lively)
F - Rule-Consciousness (Expedient vs. Rule-Conscious)
H - Social Boldness (Shy vs. Socially Bold)
I - Sensitivity (Utilitarian vs. Sensitive)
L - Vigilance (Trusting vs. Vigilant)
M - Abstractedness (Grounded vs. Abstracted)
N - Privateness (Forthright vs. Private)
O - Apprehension (Self-Assured vs. Apprehensive)
Q1 - Openness to Change (Traditional vs. Open to Change)
Q2 - Self-Reliance (Group-Oriented vs. Self-Reliant)
Q3 - Perfectionism (Tolerates Disorder vs. Perfectionist)
Q4 - Tension (Relaxed vs. Tense)

Although Cattell has contributed much to personality research through the use of factor analysis his theory is greatly criticised. The most apparent criticism of Cattell's 16 Personality Factor Model is the fact that, despite many attempts, his theory has never been entirely replicated. In 1971, Howarth and Brown's factor analysis of the

16 Personality Factor Model found ten factors that failed to relate to items present in the model. Howarth and Brown concluded *"that the 16 PF does not measure the factors which it purports to measure at a primary level"* (Eysenck & Eysenck, 1987). Studies conducted by Sell et al (1970) and by Eysenck and Eysenck (1969) also failed to verify the 16 Personality Factor Model's primary level (Noller, Law, Comrey, 1987).

Cattell and his colleagues responded to the critics by maintaining the stance that the reason the studies were not successful at replicating the primary structure of the 16 Personality Factor model was because the studies were not conducted according to Cattell's methodology. However, using Cattell's exact methodology, Kline and Barrett (1983), only were able to verify four of 16 primary factors (Noller, Law & Comrey, 1987). Despite all the criticism of Cattell"s hypothesis, his empirical findings lead the way for investigation and later discovery of the 'Big Five' dimensions of personality. Tupes and Christal (1961) simplified Cattell's variables to five recurrent factors known as extraversion or surgency, agreeableness, consciousness, emotional stability and intellect or openness (Pervin & John, 1999).

The Big Five factors and their constituent traits can be summarised as follows:

1. **Openness** - appreciation for art, emotion, adventure (**risk taking**), unusual ideas, **imagination**, curiosity, and variety of experience.
2. **Conscientiousness** - a tendency to show self-discipline (**successful**), act dutifully and aim for achievement; planned rather than spontaneous behaviour.
3. **Extraversion** - energy, positive emotions (**self-confidence**), surgency, and the tendency to seek stimulation (**forward looking**) and the company of others.
4. **Agreeableness** - a tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others.
5. **Neuroticism** - a tendency to experience unpleasant emotions easily, such as anger, anxiety, depression or vulnerability – sometimes called emotional instability.

8.4.2 Defining the Questions

The six traits described in 8.3.6 were compared to the 'Big Five' factors defined in 8.4.1. Of these the first three are of interest to us: **openness**, **conscientiousness** and **extraversion**. From these we can draw parallels to the six traits derived from the work of the expert panel. The question sets were taken from two books by Philip Carter and Ken Russell (Carter & Russell 2001 and Carter & Russell 2003) and are reproduced with permission of John Wiley & Sons Ltd on behalf of Capstone Publishing Ltd. The selection of these publications was premised on the need to produce an accessible test which would not discourage the student subjects. Much has been written on the nature of personality testing in applied psychology. The role of psychometric testing and application of tests such as the Cattell 16PF test in personnel selection is clearly documented (Cattell, Eber and Tatsuoko 1970). The developed questionnaire was used for a series of psychometric tests conducted between September 2004 and July 2007. The **Innovation Trait Index (ITI)** enables us to quantify any changes in the innovation propensity of individuals passing through the industrial design programme at Swansea Institute.

8.4.3 The Questionnaire

For the purpose of this study a specific set of questions was called for. The use of a general psychometric test was discounted on the basis that the studies aimed to produce a specific grounded theory not test an existing one. Six sets of questions were selected. Six traits – laterality (right or left hemisphere dominance), forward looking, likelihood of being successful, capacity for imaginative thinking, capacity for risk-taking and self-confidence – were clustered to create the **Innovation Trait Index.** The final questionnaire developed for the study is reproduced in the appendices (Appendix 5, p.275). For ease of use the questions were created in a Microsoft Excel 2003 spreadsheet to allow students to complete the test in the computer lab under uniform conditions.

The use of a computerised questionnaire facilitated the collection and analysis of data. The questionnaire comprised six sets of questions taken from two texts by Philip Carter and Ken Russell. Some minor changes were made to avoid potential pitfalls highlighted in guidance on questionnaire development, (Brewerton and Millward 2001) namely:

- Unfamiliar words or jargon
- Ambiguous or imprecise words or questions
- Complicated wording
- Double-barrelled questions
- Leading questions

A series of pilot questionnaires were run with individuals and organisations to determine time requirements and identify any logistical issues. The final questionnaire took approximately 35-40 minutes to complete. The length of questionnaire is in keeping with practices advised to engage the subjects (Brewerton and Millward 2001). The questionnaire was as an 'Excel' spreadsheet to make it as simple as possible for students to complete and submit. The questionnaire comprised a Title Panel with standard directions to be read by the subject, a confidential personal information form and the six questionnaires each with 25 questions. Each question had the same structure, a question followed by three possible answers, either a, b or c.

The following questionnaire has been produced as part of my PhD studies into the innovative mind. The questions need to be answered quickly - don't think about your response as your first answer is the one I need. There are no right or wrong answers to the questions - only honest ones. - Thanks - Ian Walsh					
Firstly fill in your personal details (these will remain confidential) then systematically answer the questions. There are 155 questions but the entire questionnaire can be completed in 35 minutes.					
Answer each question by typing the number **1** into the box corresponding to your answer					
Example - In answer to the question 'Which of the following appeals to you most?' I chose answer 1b					
P136/B2	1	Which of the following appeals to you most?			
P136/B2	1a	To be able to do things because I want to do them			
P136/B2	1b	to have a wonderful family life		1	
P136/B2	1c	to be highly successful in my chosen career			
Innovation Trait Index		CONFIDENTIAL			
Name:					
Age [Years]:					
Sex [M/F]:					
Current Course:					
Qualification: [Highest]					

Figure 8.17 Questionnaire Title Panel

8.4.4 Assessing the Resulting Data

The aims of this thesis have been examined and well documented throughout the preceding chapters. It has not been the intention to generate a new general theory of personality or even to test an existing theory, but to specifically identify and test those aspects of personality which govern an individual's propensity to be innovative.

Thus the analysis of the results of the Innovation Trait test is very specific and discrete in its application. The purpose is to answer the questions set at the end of chapter 7:

1. Can the effect of the programme of study on the individual's propensity to innovate be quantified?
2. What is the effect on the individual of studying under the industrial design innovation model presented here compared with students studying on a more traditional design programme?
3. To what extent does a graduate from the industrial design programme demonstrate a propensity for innovation compared to graduates from other programmes and known innovators?

With the psychometric questions having been taken from Carter and Russell (2001 & 2003) it is logical that the analysis is also guided by them. Reference has been made in the analysis to the work of Kline, (1993), who has reviewed and compared the major personality theories and psychometrics of personality. The following tables give the analysis for each question set: (Figures 8.18 to 8.23).

Forward Looking				
Lower Band	**L**	**Mid Band**	**U**	**Upper Band**
0-24		**25-39**		**40-50**
Resistant to change. Not particularly interested in moving forward. Can be overwhelmed by new technology. Sentimental.		Forward looking but respectful of tradition. Past experiences make us what we are today. Not afraid of the future but nostalgic about the past.		Continually looking forward. Continually planning for the future. Change is good. Excited by future opportunities. Interested in new technology. Philosophy is to continually move forward.

Figure 8.18 Personality analysis for 'Forward Looking' (after Carter & Russell, 2003)

Likelihood of Being Successful				
Lower Band	**L**	**Mid Band**	**U**	**Upper Band**
0-19		**20-39**		**40-50**
Not ambitious. Shuns responsibility in work life. Prefers home and family life to career progression.		Hard working but troubled by self-doubt. Tends to serve the interest of others above self. Ambitious but lacks sufficient self-confidence.		Hard working. Strong character. Persistence. Flair and imagination. Ambitious.

Figure 8.19 Personality analysis for 'Likelihood of being Successful' (after Carter & Russell, 2001)

Capacity for Imaginative Thinking				
Lower Band	L	Mid Band	U	Upper Band
0-15		16-34		35-50
Not particularly imaginative. Content with one's lot in life. Not driven to be new or original.		Generally conventional and respectable. Open minded and unconventional in some aspects of life.		Highly imaginative. Unconventional. Can be frustrated and dissatisfied. Inventive and free thinking.

Figure 8.20 Personality analysis for 'Capacity for Imaginative Thinking' (after Carter & Russell, 2001)

Capacity for Risk Taking				
Lower Band	L	Mid Band	U	Upper Band
0-24		25-39		40-50
Steady and sensible. Not likely to take risks.		Balanced approach to risk. Not averse to taking the occasional risk. Measured and calculated risk taker.		A risk taker. Can be inclined to recklessness. At the higher end can be prone to gambling rather than calculating. Likely to be the person who either makes a fortune or loses one.

Figure 8.21 Personality analysis for 'Capacity for Risk Taking' (after Carter & Russell, 2001)

Self-Confidence (Assuredness and self-reliance in one's own abilities)				
Lower Band	L	Mid Band	U	Upper Band
0-17		18-35		36-50
Lacking any self-confidence. Self-deprecating. Overly modest. Nervous in the company of others.		Quietly confident. Inclined to take measured risks. Prefers security without taking too many chances. Careful not to be over-confident. Weighs up the options before taking decisions.		Very confident. Positive personality. Assured and self-reliant. Accepting of change. Inclined to embrace change in the workplace as a way of self-advancement.

Figure 8.22 Personality analysis for 'Self-Confidence' (after Carter & Russell, 2003)

Laterality (Balance between left and right hemispheres in the brain)				
Left-Side Dominant	L	Balanced	U	Right-Side Dominant
0-30		30-47		48-60
Logical. Conscious thought. Sequential processing (part to whole). Methodical. Intellectual. Analytical. Scientific. Verbal intelligence.		Good balance between right and left dominance. Can cause conflict in deciding which way to tackle problems. Can see the 'big picture' and the essential details at the same time. Can balance creativity with logic to turn a concept into reality.		Intuitive. Subconscious thought. Holistic processing and visualising (sees the 'big picture' first). Creative. Sensuous. Synthetic. Artistic, musical. Practical Intelligence.

Figure 8.23 Personality analysis for 'Laterality' (after Carter & Russell, 2003)

8.5 Piloting the Questionnaire

8.5.1 Pilot Questionnaire 1

The test was piloted on ten individuals from a variety of backgrounds,

- Four innovation managers
- Two engineers
- Two designers
- Two educationalists

The pilot questionnaire was a reduced version which excluded the question-set on 'confidence'. The Data was collated and analysed graphically and the results discussed with the participants to aid the refinement of the final questionnaire.

	Test Subjects									
Question Sets	**P1/01**	**P1/02**	**P1/03**	**P1/04**	**P1/05**	**P1/06**	**P1/07**	**P1/08**	**P1/09**	**P1/10**
Laterality	45	29	32	22	30	34	24	51	43	23
Forward Looking	41	38	34	29	35	36	23	33	42	18
Likely to be a success	43	37	38	40	46	29	35	25	37	34
Imaginative	35	32	26	33	39	29	25	24	31	25
Risk Taking	37	38	35	23	43	35	31	32	33	23
Totals	**201**	**174**	**165**	**147**	**193**	**163**	**138**	**165**	**186**	**123**

Figure 8.24 Pilot 1 Questionnaire Data-Set

The pilot test confirmed the logistics of the testing process and validated the structure of the test. The data was visualised using a line graph and a radar graph to map the results against the upper and lower bands for each personality trait. The aim was to determine the optimum method of visualising the data and create a clear method for communicating the level of innovation propensity.

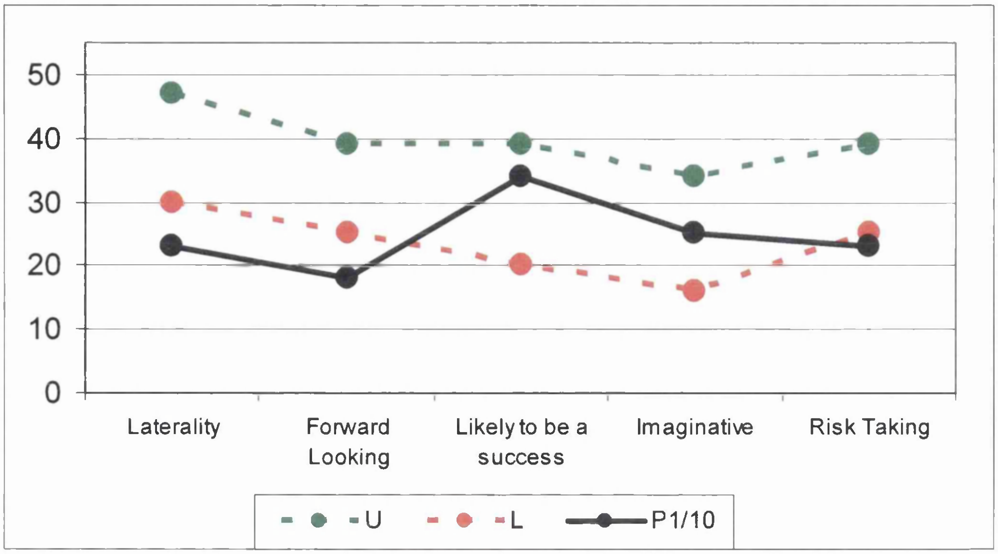


Figure 8.25 Pilot 1 Questionnaire Line Graph Plot

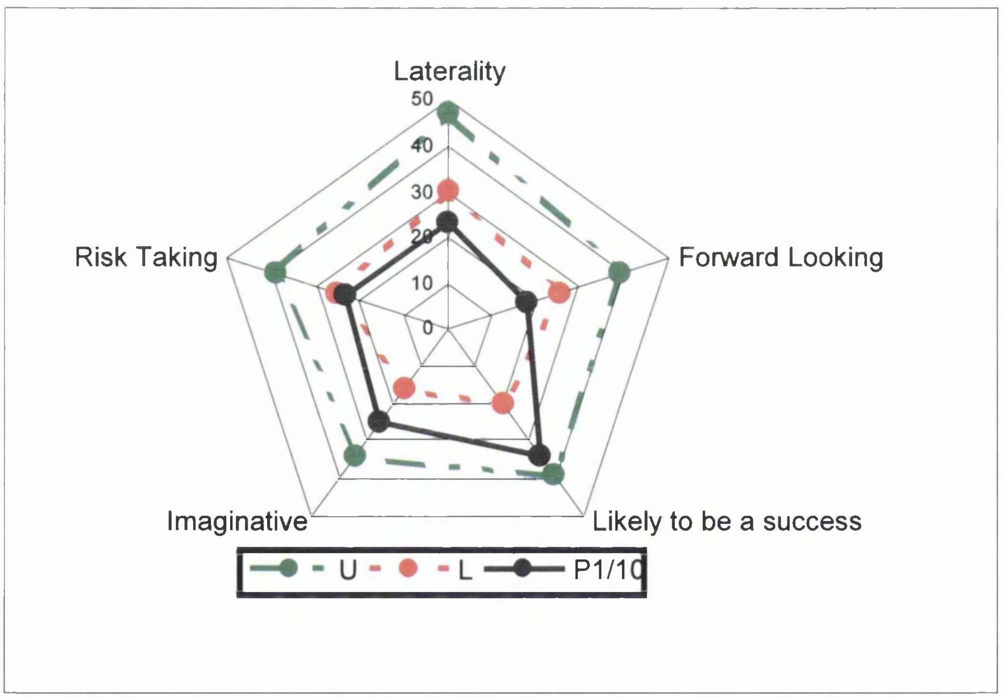


Figure 8.26 Pilot 1 Questionnaire Radar Graph Plot

Visualising the data in this way provides an instant 'snap-shot' of the individual's innovation score. With reference to Carter & Russell (2001, 2003) from Figure 8.25 and Figure 8.26 we can readily see that subject P1/10 has a low score on laterality indicating a left-hemisphere dominant brain which indicates an analytical mindset. In terms of the other factors the immediate visual analysis indicates a conservative and cautious individual who is hard working and imaginative. Such a quick graphical representation is helpful for providing simple visual comparisons between individuals.

8.5.2 Pilot Questionnaire 2

The questionnaire was developed to take account of feedback from the initial pilot group.

	Test Subjects			
Question Sets	P2/01	P2/02	P2/03	P2/04
Laterality	48	39	23	45
Forward Looking	44	18	18	41
Likely to be a success	42	36	34	43
Imaginative	38	27	25	35
Risk Taking	40	26	23	37
Confidence	46	40	40	46
Totals	**258**	**186**	**163**	**247**

Figure 8.27 Pilot 2 Questionnaire Data-Set

The test was trialled with four subjects, a designer, an educationalist, a scientist and a known innovator. Once again with reference to Carter & Russell (2001, 2003) from Figure 8.28 and Figure 8.29 we can determine that subject P2/02 has a mid-range score on laterality indicating an even balance between right and left hemispheres. This is evidence of the subject having a balance between the creative and analytical functions. In terms of the other factors the immediate visual analysis indicates a very conservative and cautious individual who tends to reminisce about the 'good old days' and cherishes tradition. This subject has a high level of self-belief and is self-confident, hard working with a degree of imagination.

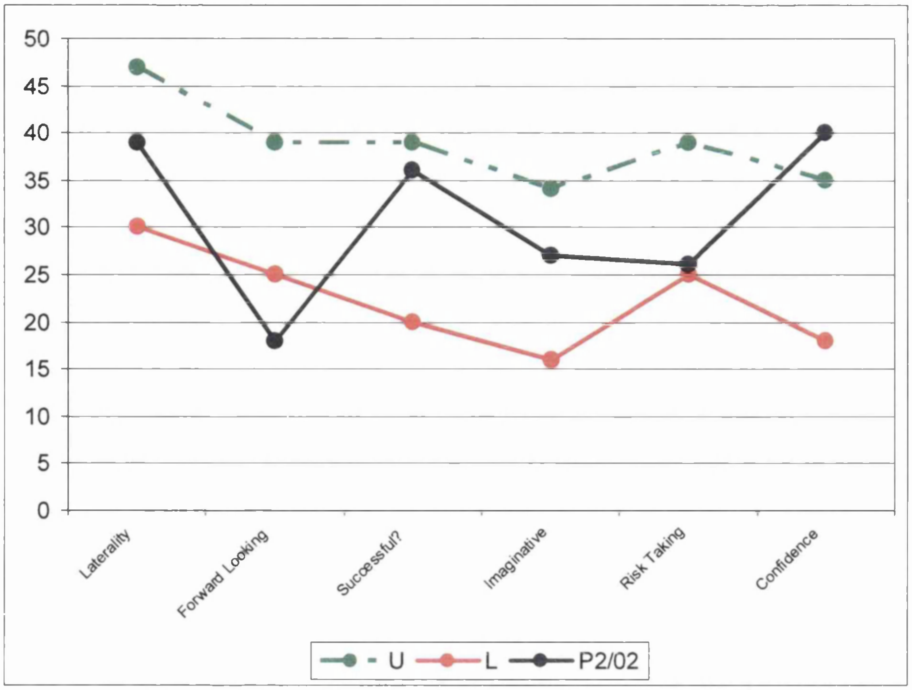


Figure 8.28 Pilot 2 Questionnaire Line Graph Plot

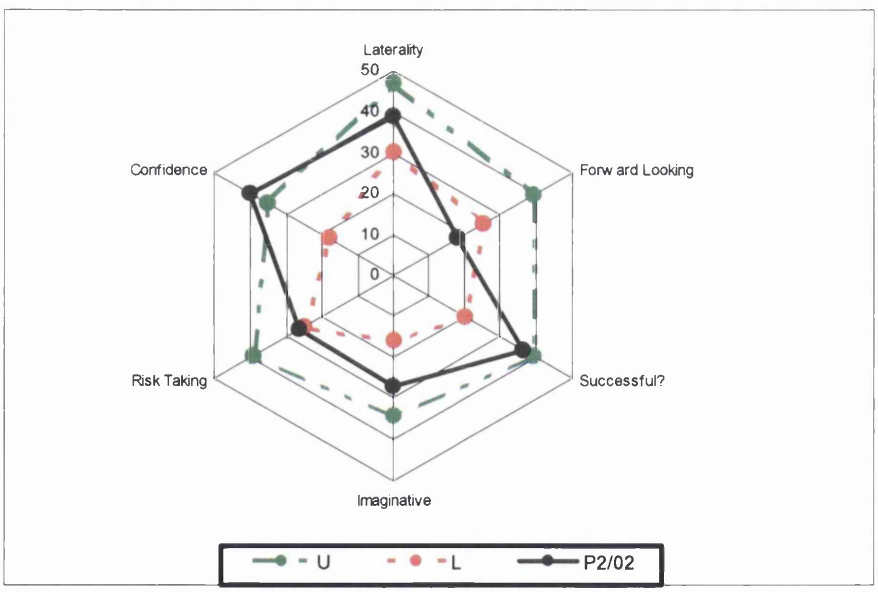


Figure 8.29 Pilot 2 Questionnaire Radar Graph Plot

The pilot tests allowed the questions to be refined and the layout of the questionnaire to be developed to ensure ease of readability and navigation. Attention now turned to the establishment of a benchmark against which to measure innovation propensity.

8.6 Benchmarking the Final Questionnaire

8.6.1 The Role of Laterality

There was a need to benchmark the test, so one of the test groups selected was of 'Known Innovators'. These were selected following a short interview and dependent upon them meeting two or more of the following criteria:

1. Have been responsible for establishing an innovative business
2. Have been involved in innovation research for more than five years
3. Hold intellectual property rights for innovative products or processes

On the basis of the criteria, 14 'Known Innovators' were selected to take part in the study. Each completed the psychometric questionnaire under the same conditions as the student subjects. It was essential to establish a robust benchmark against which to evaluate the student data.

From the initial pilot tests a distinction emerged between 'Laterality' and the other five traits. It seemed apparent that high scores 'Forward Looking', 'Likelihood of Being Successful', 'Capacity for Imaginative Thinking', 'Capacity for Risk-Taking' and 'Self-confidence' were not dependent on the lateral dominance of the brain. Early mapping of the data on a scatter graph was used to test this hypothesis. From the data (
Figure 8.30) we plot the 'Laterality' (Left/Right Dominance) scores for each 'Known Innovator' against the left, right and balanced brain bands (Figure 8.31).

		KI/01	KI/02	KI/03	KI/04	KI/05	KI/06	KI/07	KI/08	KI/09	KI/10	KI/11	KI/12	KI/13	KI/14	KI/Median	Standard Deviation
Laterality		32	30	29	34	38	38	43	36	43	39	32	30	31	36	35	4.68
Forward Looking		34	35	38	36	36	36	42	36	47	41	33	40	40	36	36	3.76
Successful		38	46	37	29	28	31	37	28	44	39	34	33	44	35	36	5.94
Imaginative		26	39	32	29	29	32	31	32	35	33	22	24	29	34	31.5	4.47
Risk Taking		35	43	38	35	40	38	33	31	40	39	34	38	34	22	36.5	5.12
Confidence		37	36	35	35	41	35	35	32	44	40	40	38	42	32	36.5	3.67
Total		170	199	180	164	174	172	178	159	210	192	163	173	189	159	173.5	15.35
Median		35.00	39.00	37.00	35.00	36.00	35.00	35.00	32.00	44.00	39.00	34.00	38.00	40.00	34.00	35.50	
Standard Deviation		4.74	4.66	2.55	3.49	6.06	2.88	4.22	2.86	4.64	3.13	6.54	6.47	6.18	5.67		

Figure 8.30 Psychometric Data for Known Innovators

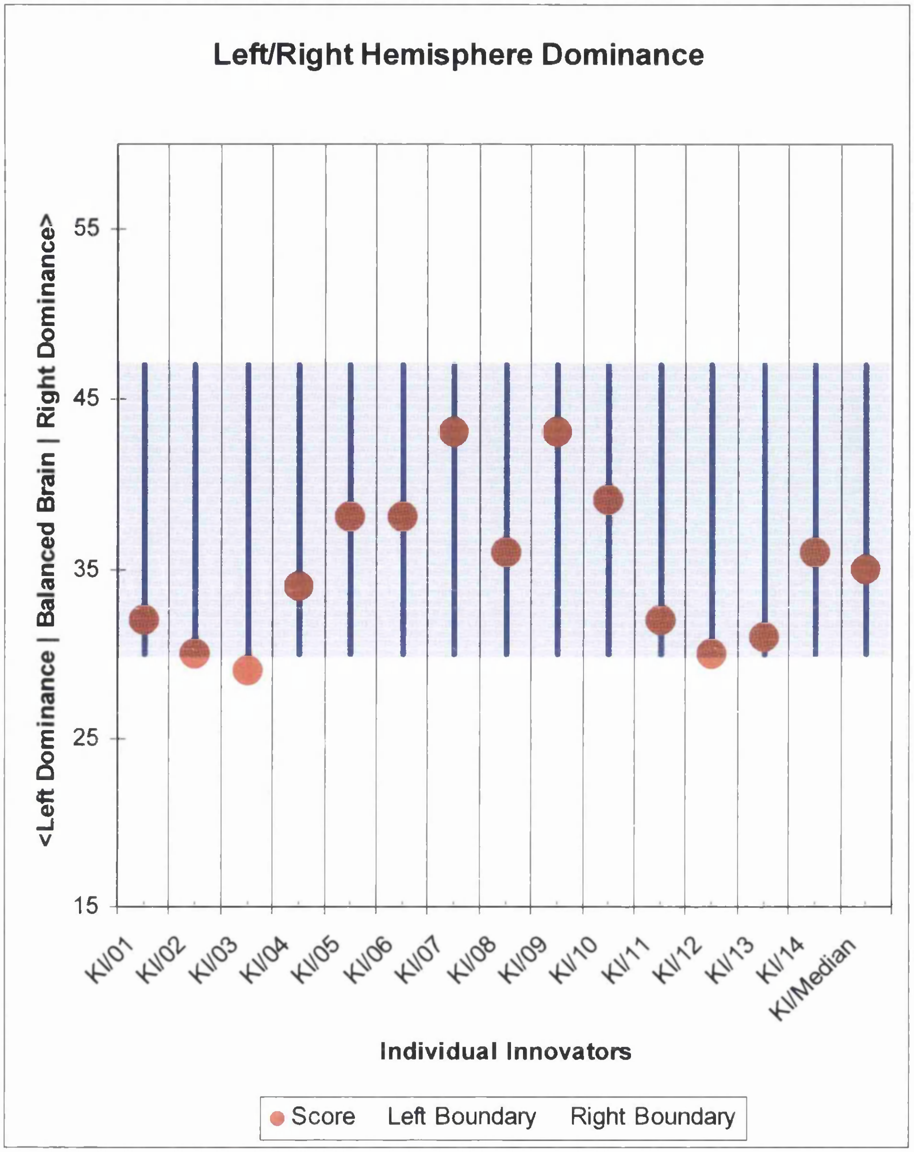


Figure 8.31 Laterality of Known Innovators

From the graph it is evident that all the known innovators tested exhibit a balance between the left and right hemispheres of brain activity. They demonstrate no dominance by either hemisphere. The analysis indicates that this gives them the ability to grasp the 'big picture' whilst handling the details of development and implementation.

We now take the data for Industrial Design graduates, Engineering graduates and Automotive Design graduates to determine if any patterns emerge.

		IDGrad/01	IDGrad/02	IDGrad/03	IDGrad/04	IDGrad/05	IDGrad/06	IDGrad/07	ID/Median
Laterality		33	51	42	43	36	42	47	42
Forward Looking		39	40	36	34	37	39	38	38
Successful		37	40	31	33	35	37	39	37
Imaginative		31	34	33	28	34	38	31	33
Risk Taking		34	39	31	29	30	38	37	34
Confidence		37	36	33	37	39	38	40	37
Total		178	189	164	161	175	190	185	178
Median		37.00	39.00	33.00	33.00	35.00	38.00	38.00	
Standard Deviation		3.13	2.68	2.05	3.70	3.39	0.71	3.54	

Figure 8.32 Psychometric Data for Industrial Design Graduates

		EG/01	EG/02	EG/03	EG/04	EG/05	EG/06	EG/07	EG/08	EG/09	EG/10	EG/11	EG/12	EG/Median
Laterality		34	24	30	31	31	20	25	22	37	29	34	24	29.5
Forward Looking		39	29	39	37	38	37	27	39	30	39	36	22	37
Successful		36	35	33	39	33	34	32	43	38	38	35	36	35.5
Imaginative		26	19	30	39	28	35	25	16	33	30	25	27	27.5
Risk Taking		42	29	36	28	21	25	21	24	32	28	20	22	26.5
Confidence		44	35	40	33	37	28	25	26	38	35	36	29	35
Total		187	147	178	176	157	159	130	148	171	170	152	136	158
Median		39.00	29.00	36.00	37.00	33.00	34.00	25.00	26.00	33.00	35.00	35.00	27.00	
Standard Deviation		7.06	6.54	4.16	4.71	7.02	5.07	4.00	11.15	3.63	4.85	7.44	5.81	

Figure 8.33 Psychometric Data for Engineering Graduates

		AutoGrad/01	AutoGrad/02	AutoGrad/03	AutoGrad/04	AutoGrad/05	AutoGrad/06	AutoGrad/07	AutoGrad/Median
Laterality		40	42	39	30	35	43	42	40
Forward Looking		35	31	25	37	39	21	42	35
Successful		35	26	33	40	42	31	43	35
Imaginative		30	35	26	29	29	36	35	30
Risk Taking		31	37	32	35	39	30	33	33
Confidence		41	22	36	36	39	30	42	36
Total		172	151	152	177	188	148	195	172
Median		35.00	31.00	32.00	36.00	39.00	30.00	42.00	
Standard Deviation		4.34	6.22	4.72	4.04	4.98	5.41	4.64	

Figure 8.34 Psychometric Data for Automotive Design Graduates

The resulting graph plots the median 'Laterality' score for each group studied. A pattern of distribution emerges which clearly reveals Design graduates to be influenced by the right side of the brain, though still within the central 'balanced' category. Engineering graduates are revealed to be influenced strongly by the left side of the brain, with the median value falling just outside the 'balanced' category as defined by Carter and Russell.

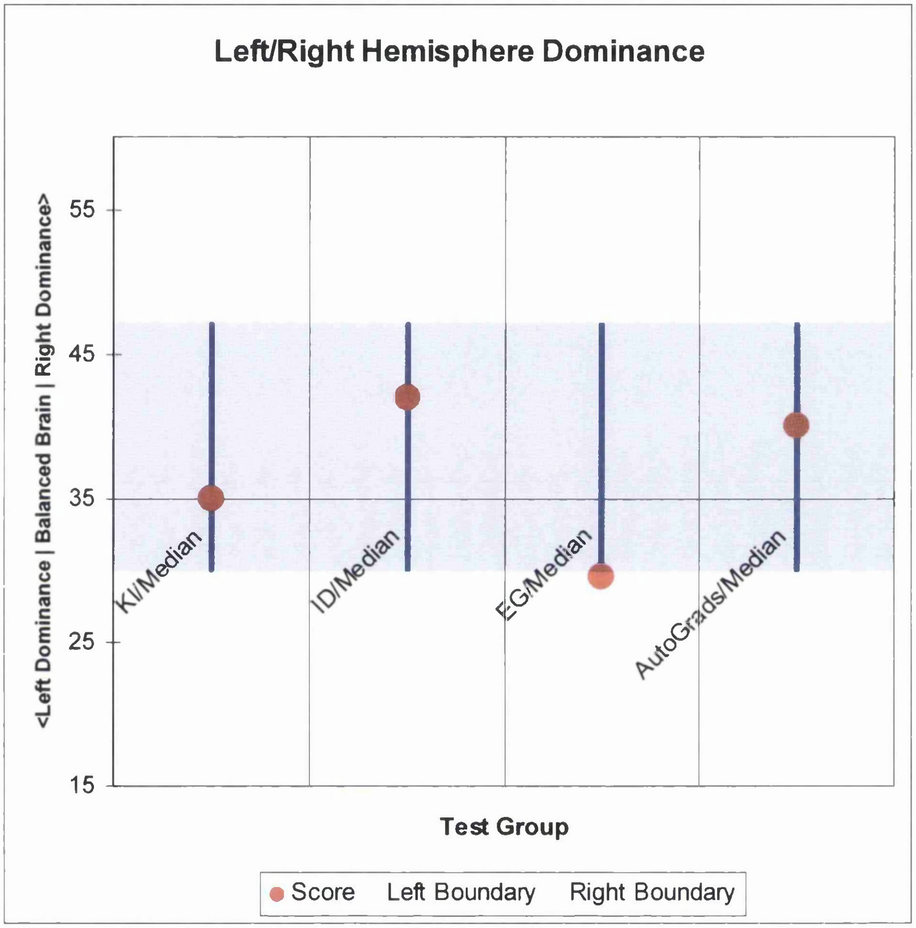


Figure 8.35 Comparative Laterality by Test Group

Known Innovators are found in the balanced brain band of the laterality spectrum, but with a median of 35 they are found more influenced by the left hemisphere than the right. This may be explained by the makeup of the group which contained a predominance of individuals from a science and technology background.

8.6.2 Spearman's Rank Correlation Test

Nonparametric methods such as Spearman's may be used to measure the relationship or correlation between two variables, X and Y. Rather than using precise values the data is ranked from 1 to N in order of size or importance, etc. If X and Y are ranked in such a manner, the coefficient of rank correlation or Spearman's formula for rank correlation is given by:

$$\rho = 1 - \frac{6 \sum D^2}{N(N^2 - 1)}$$

where D denotes the difference between the ranks of corresponding values of X and Y, and where N is the number of pairs of values (X,Y) in the data. The rank-order correlation coefficient can be used with any variables where the data are ranked. If the original data are measurements on some scale, they can be converted to ranks first. Figure 8.37 contains the ranked data for our Known Innovators. The aim of the test is to determine any relationship between the Innovation Trait Scores and laterality (left/right hemisphere dominance). The test is a measurement for statistical significance. The null hypothesis is that no general pattern of agreement (positive) or disagreement (negative) between the rankings exists.

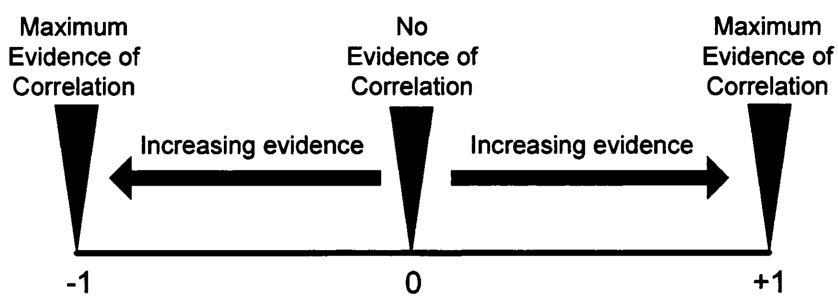


Figure 8.36 Value of ρ and strength of evidence

Conducting a Spearman's Rank Correlation Test on the group of Known Innovators enables us to determine if any correlation exists between Laterality and the total Innovation Trait Score.

Subject	Laterality	*Rank*	ITI	*Rank*
KI/01	32	5.5	170	5
KI/02	30	2.5	199	13
KI/03	29	1	180	10
KI/04	34	7	164	4
KI/05	38	10.5	174	8
KI/06	38	10.5	172	6
KI/07	43	13.5	178	9
KI/08	36	8.5	159	1.5
KI/09	43	13.5	210	14
KI/10	39	12	192	12
KI/11	32	5.5	163	3
KI/12	30	2.5	173	7
KI/13	31	4	189	11
KI/14	36	8.5	159	1.5
Stand. Dev		**4.16**		**4.18**
Covariance			**1.11**	
Spearman's Rank Correlation			**0.06**	

Figure 8.37 Spearman's Rank Correlation for Laterality and ITI Score in Known Innovators

With a rank correlation of 0.06 we can say that there is no significant correlation between laterality and propensity to innovate. For further confirmation, we run the test on the Industrial Design and Automotive Design graduates.

Subject	Laterality	*Rank*	ITI	*Rank*
ID/01	33	2	178	9
ID/02	51	14	189	12
ID/03	42	8.5	164	5
ID/04	43	11.5	161	4
ID/05	36	4	175	7
ID/06	42	8.5	190	13
ID/07	47	13	185	10
AutoGrad/01	40	6	172	6
AutoGrad/02	42	8.5	151	2
AutoGrad/03	39	5	152	3
AutoGrad/04	30	1	177	8
AutoGrad/05	35	3	188	11
AutoGrad/06	43	11.5	148	1
AutoGrad/07	42	8.5	195	14
Stand. Dev		**4.13**		**4.18**
Covariance			**-0.36**	
Spearman's Rank Correlation			**-0.02**	

Figure 8.38 Spearman's Rank Correlation for Laterality and ITI Score in Industrial Design and Automotive Design Graduates

The analysis of the industrial and automotive design graduates lends further support to the notion that innovativeness is independent of hemispherical dominance. However, there is a degree of caution when dealing with values which are more polarised either towards the left or right hemisphere, as the following analysis of Engineering graduates illustrates.

Subject	Laterality	*Rank*	ITI	*Rank*
EG/01	34	10.5	187	12
EG/02	24	3.5	147	3
EG/03	30	7	178	11
EG/04	31	8.5	176	10
EG/05	31	8.5	157	6
EG/06	20	1	159	7
EG/07	25	5	130	1
EG/08	22	2	148	4
EG/09	37	12	171	9
EG/10	29	6	170	8
EG/11	34	10.5	152	5
EG/12	24	3.5	136	2
Stand. Dev		**3.59**		**3.61**
Covariance			**6.50**	
Spearman's Rank Correlation			**0.50**	

Figure 8.39 Spearman's Rank Correlation for Laterality and ITI Score in Engineering Graduates

Figure 8.39 provides an indication that, as the laterality score moves away from balance to show a definite hemispherical dominance, there is a greater correlation to the overall ITI score. However, the Spearman's Rank Correlation value remains low and we can say that, with the values we have, the Innovation Trait score is not dependent on laterality.

8.6.3 Correlation Test of Individual Innovation Traits

We now compare the individual innovation traits for Industrial Design undergraduates against laterality. The test compares data on each trait captured at both Level 4 and Level 5 with data from the level 5 laterality test. The results of 0.22; 0.27; -0.14; -0.12; -0.31; 0.32; 0.20; 0.42; -0.03; 0.14; -0.05; -0.07 indicate a low potential correlation between the individual traits and laterality. The outcomes demonstrate that there is no significant relationship between the innovation traits and the relative dominance of left/right hemispheres.

Laterality L5	Rank	ITI L4	Rank	Fwd Looking L4	Rank	Fwd Looking L5	Rank	Imaginative L4	Rank	Successful L5	Rank	Imaginative L4	Rank	Imaginative L5	Rank	Risk Taking L4	Rank	Risk Taking L5	Rank	Confidence L4	Rank	Confidence L5	Rank	ITI L5	Rank
44	14	160	8	33	11.5	27	2	28	4.5	21	1	29	7	29	7.5	37	12.5	33	6	33	8	28	1.5	138	1.5
39	9	137	5	25	3	32	7.5	30	7	31	4	26	3.5	25	2.5	26	3.5	30	4	30	6	32	6	150	4
37	6	163	9.5	33	11.5	34	11	35	12	29	3	30	9.5	31	9	33	9	35	9	32	7	31	4.5	160	7
34	5	163	9.5	30	8	29	4.5	34	10.5	36	11	30	9.5	32	10	32	6.5	34	7.5	37	12	39	10.5	170	8
30	1	136	4	24	2	30	6	34	10.5	35	8.5	27	5	28	6	23	1	29	3	28	3.5	30	3	152	5.5
31	2	125	1	27	5.5	28	3	25	2	28	2	24	1	24	1	24	2	27	1	25	2	31	4.5	138	1.5
42	12	126	2	23	1	25	1	21	1	32	5	28	6	25	2.5	32	6.5	34	7.5	22	1	28	1.5	144	3
42	12	179	14	34	13	38	13	33	8.5	33	6	36	14	33	12	39	14	40	12.5	37	12	40	12	184	13.5
33	3.5	153	7	26	4	33	9	27	3	35	8.5	30	9.5	29	7.5	33	9	41	14	37	12	41	13	179	11
41	10	172	12	31	9.5	34	11	36	13	35	8.5	34	12.5	34	14	30	5	31	5	41	14	42	14	176	10
33	3.5	147	6	31	9.5	34	11	29	6	39	13.5	25	2	27	4.5	33	9	40	12.5	29	5	33	7.5	173	9
42	12	135	3	27	5.5	29	4.5	28	4.5	35	8.5	26	3.5	27	4.5	26	3.5	28	2	28	3.5	33	7.5	152	5.5
38	7.5	170	11	29	7	32	7.5	38	14	39	13.5	30	9.5	33	12	37	12.5	37	10.5	36	9.5	39	10.5	180	12
38	7.5	173	13	36	14	39	14	33	8.5	37	12	34	12.5	33	12	34	11	37	10.5	36	9.5	38	9	184	13.5
Std D	4.16		4.18		4.17		4.16		4.17		4.13		4.13		4.15		4.15		4.17		4.16		4.16		4.17
Covariance		3.82		4.69		-2.35		-2.02		-5.40		5.48		3.50		7.31		-0.56		2.33		-0.92		-1.23	
Spearman's		0.22		0.27		-0.14		-0.12		-0.31		0.32		0.20		0.42		-0.03		0.14		-0.05		-0.07	

Figure 8.40 Spearman's Rank Correlation Table for Individual Innovation Traits vs. Laterality (Industrial Design)

8.6.4 Comparative Analysis of Individual Responses

What is clear from the data is that laterality is an indicator of potential innovativeness, as innovators are required to balance creativity with logic. Extremes on either side lack the necessary balance to realise their concepts.

Innovation Trait Score vs. Laterality

Figure 8.41 maps the relationship between the ITI scores for each of the four study groups. Typically, the Design graduates exhibit a greater propensity towards innovation combined with a right/balanced brain. The Engineering graduates exhibit a lower propensity towards innovation combined with a left hemisphere dominant brain. The Known Innovator group clearly present a balanced distribution. We shall use the known innovator data as our check group for the remaining analysis of the individual traits.

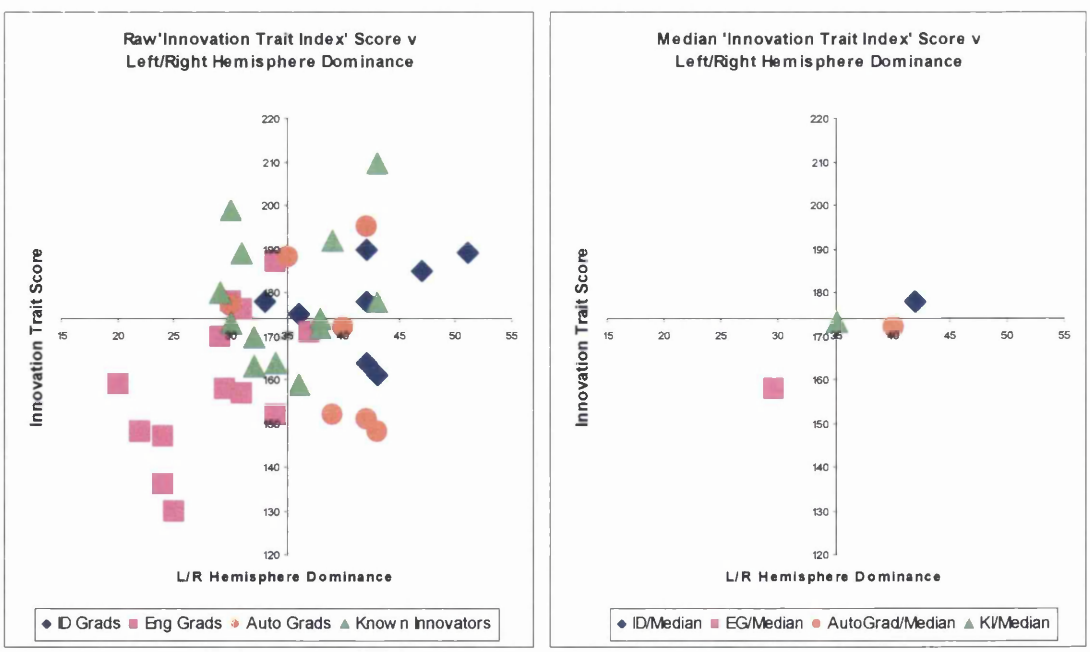


Figure 8.41 Innovation Trait Score vs. Laterality

Forward Looking Score vs. Laterality

Figure 8.42 maps the relationship between 'Forward Looking' and 'Laterality' for each of the four study groups. The graph indicates a broad distribution of data for each group. The median data for each group demonstrates a convergence in the outcomes. Consequently, it would appear that there is no significant evidence of difference in the relative tendency for forward looking between the four groups.

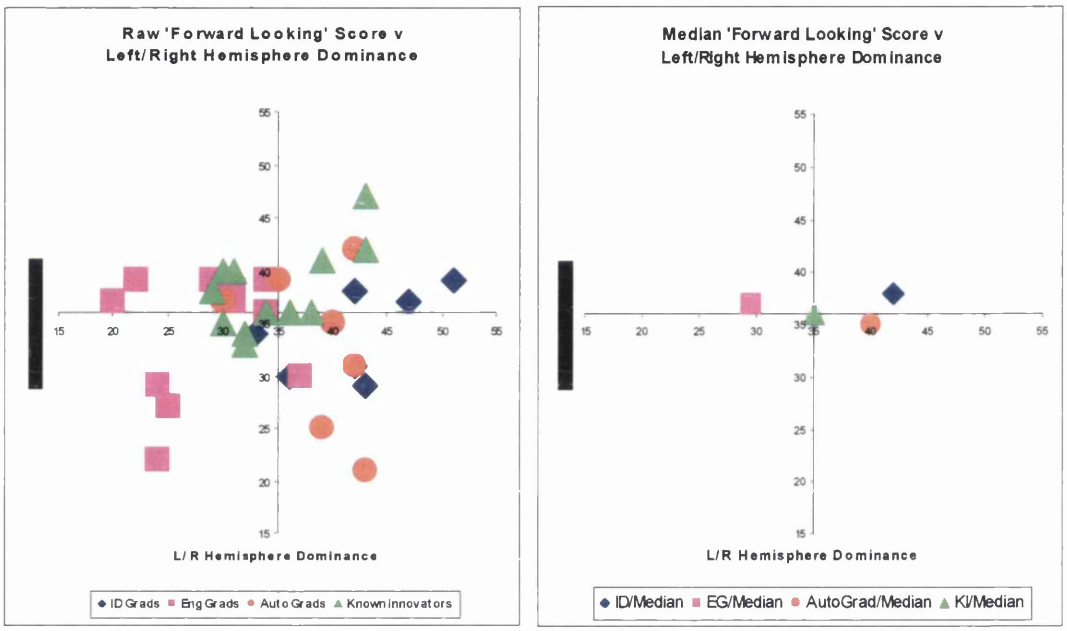


Figure 8.42 Forward Looking Score vs. Laterality

Likely to be a Success Score vs. Laterality

Figure 8.43 maps the relationship between 'Likely to be Successful' and 'Laterality' for each of the four study groups. The data forms a tight distribution about the median. There seems to be little statistical evidence of significant difference between the groups studied.

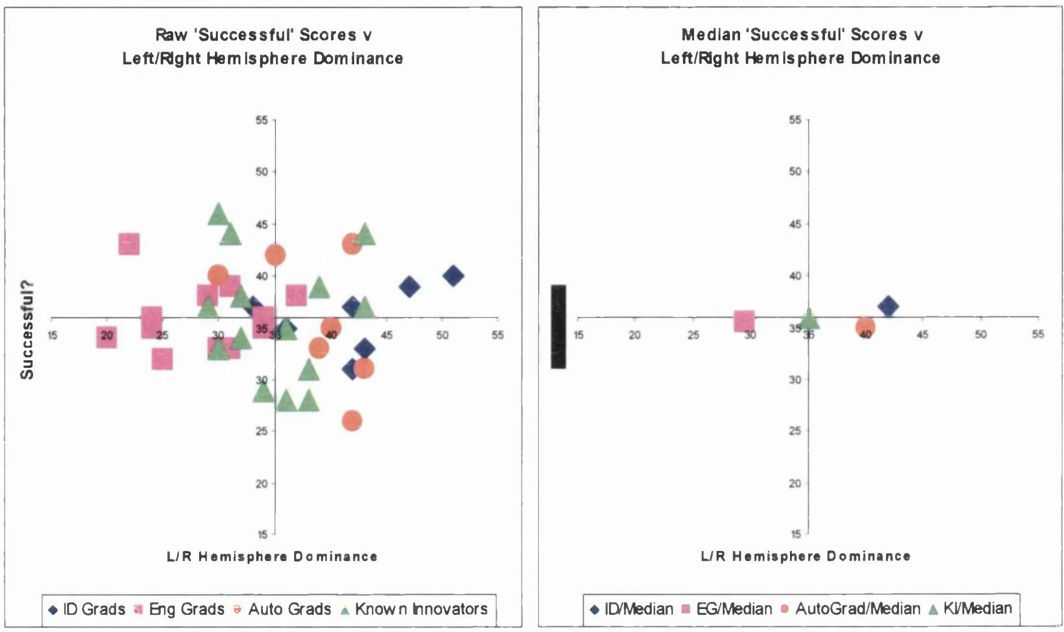


Figure 8.43 Likely to be a Success Score vs. Laterality

Imaginative Score vs. Laterality

Figure 8.44 maps the relationship between 'Capacity for Imaginative Thinking' and 'Laterality' for each of the four study groups. Here we see evidence of potentially significant difference between the groups studied. The distribution of raw data exhibits greater breadth, with the results for the Industrial Design group showing a marked difference from that of the Engineering graduates.

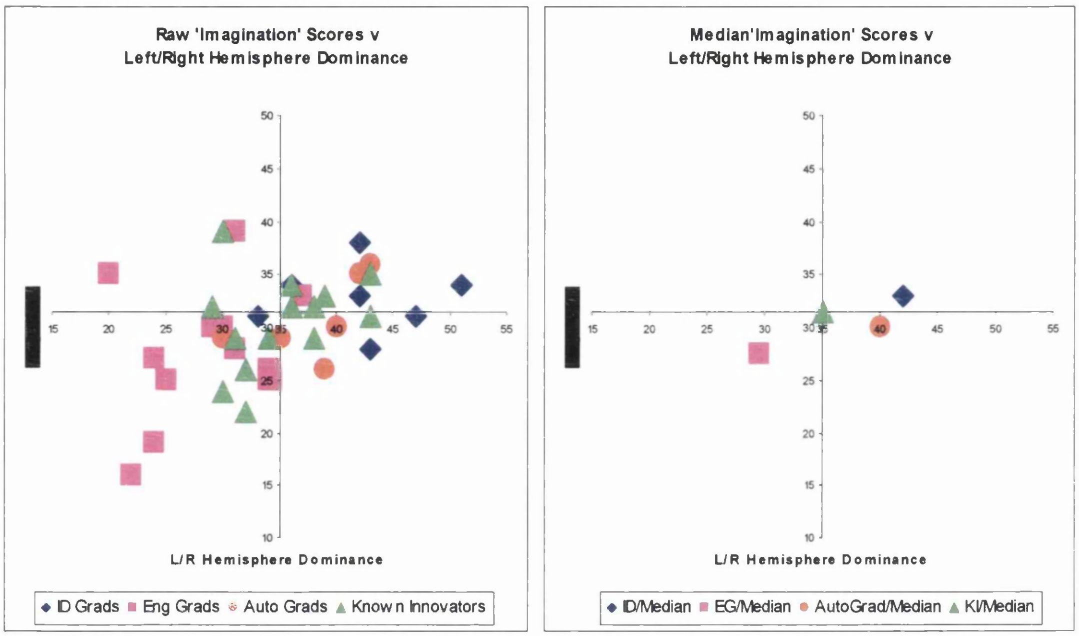


Figure 8.44 Imaginative Score vs. Laterality

Risk Taking Score vs. Laterality

Figure 8.45 maps the relationship between 'Capacity for Risk Taking' and 'Laterality' for each of the four study groups. It is here that we see the widest distribution of values. There is a close relationship between the graduate designers with risk taking values of 34 for Industrial Design and 33 for Automotive Design graduates comparing favourably with the value of 36.5 for Known Innovators. The value for Engineering graduates falls far short with a median value of 26.5.

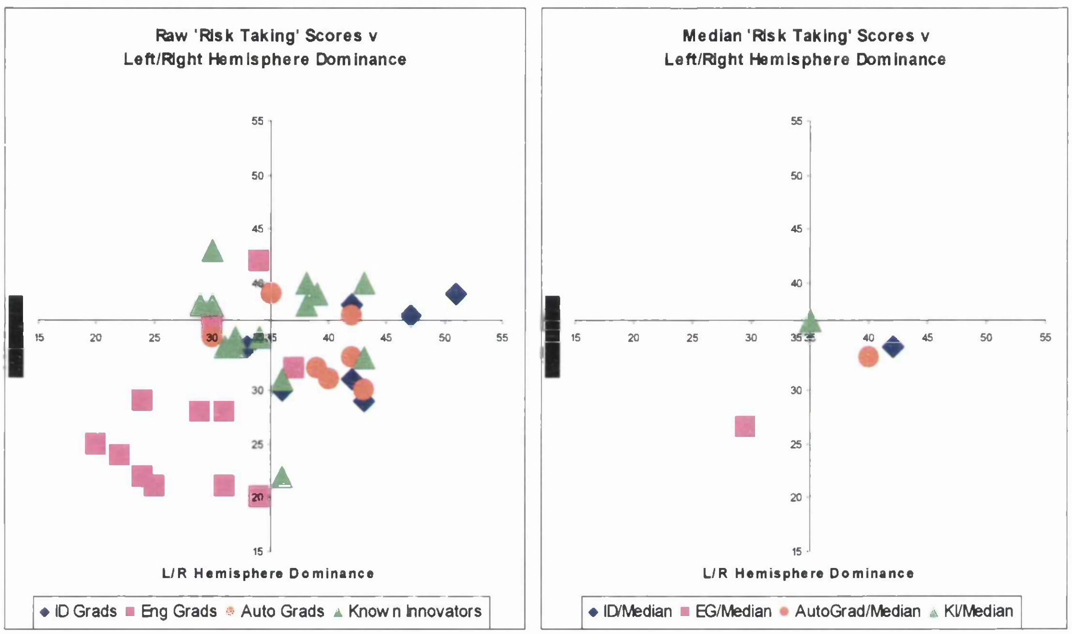


Figure 8.45 Risk Taking Score vs. Laterality

Confidence Score vs. Laterality

Figure 8.46 maps the relationship between 'Self-Confidence' and 'Laterality' for each of the four study groups. The test of self-confidence is a measure of assuredness and self-reliance in one's own abilities. It produced a very tight distribution of results but once again the Industrial Design graduates tested higher than their Engineering or Automotive Design counterparts.

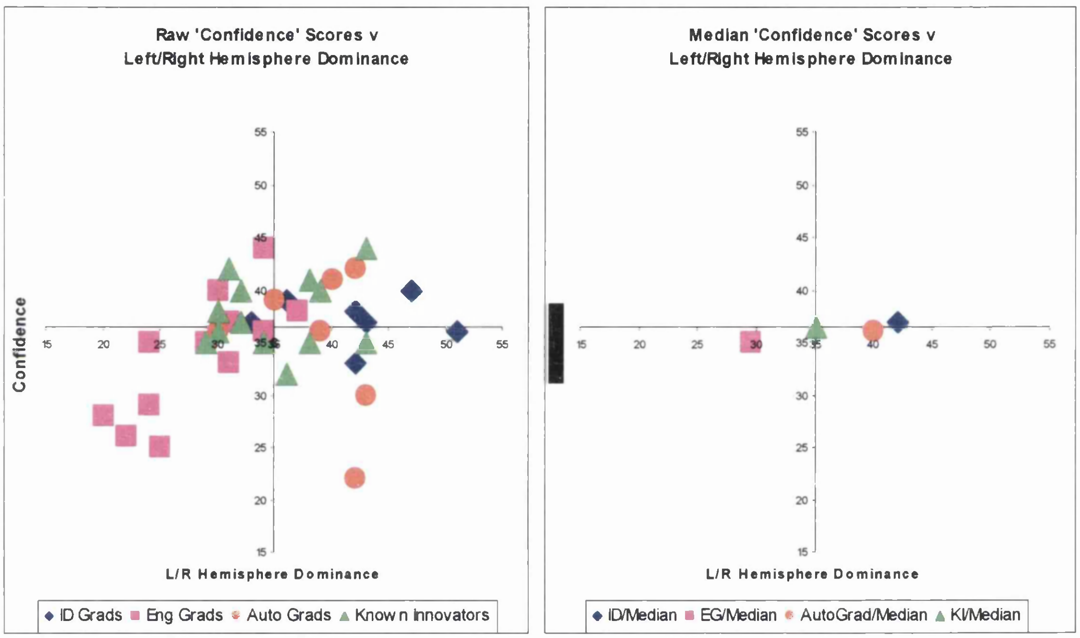


Figure 8.46 Confidence Score vs. Laterality

8.7 Comparing Median Data with Personality Bands

Despite evidence from the median data for each of the traits in the Innovation Trait test, the graphical analysis alone is insufficient to demonstrate verifiable difference. We now consider the relationship of the median data to the personality bands defined by Carter and Russell.

8.7.1 Personality Analysis of 'Forward Looking' Trait

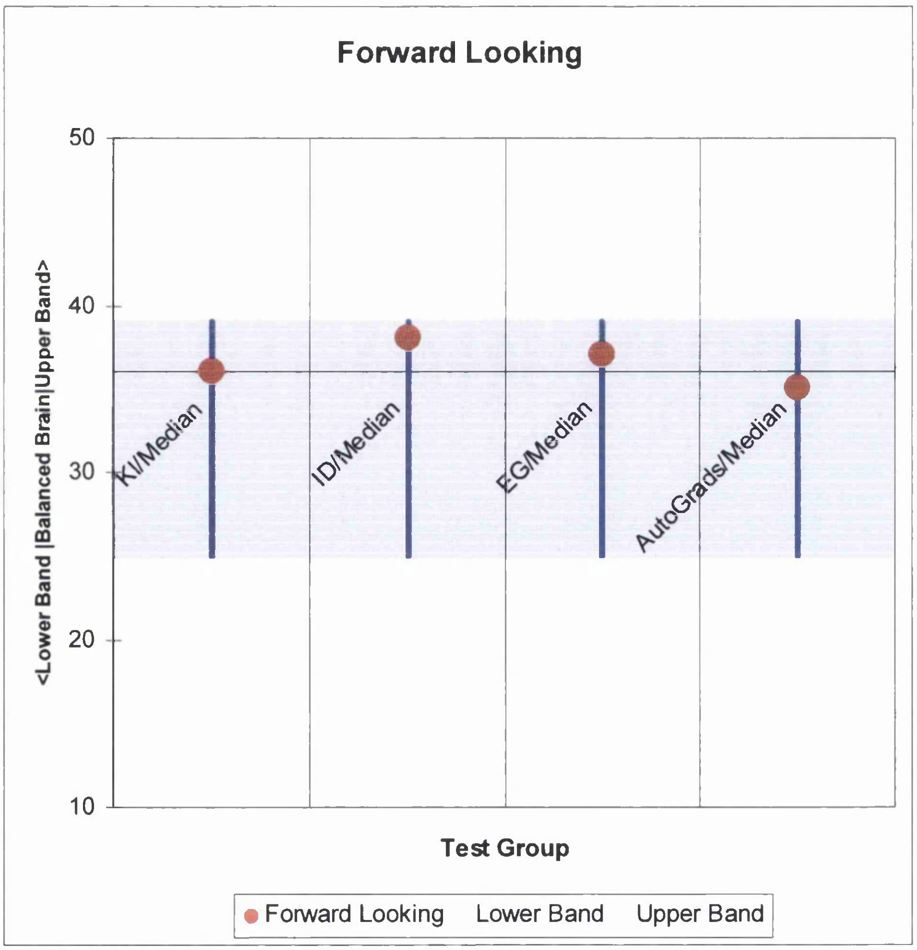


Figure 8.47 Mapping Median Data for 'Forward Thinking' against Carter and Russell's Personality Bands

The data for each group indicates that in each case the subjects studied are forward looking but respectful of tradition. Their responses indicate they are not afraid of the future and are continually looking forward. Of the three groups, only the Automotive

Designers have a lower score than the Known Innovators. Despite this, each group demonstrates a positive philosophy regarding future change and the advancement of technology. From this data it is difficult to differentiate between the groups regarding their attitudes to innovation. It is interesting to note that the Industrial Design group is the most positive when it comes to change and future possibilities.

8.7.2 Personality Analysis of 'Likely to be Successful' Trait

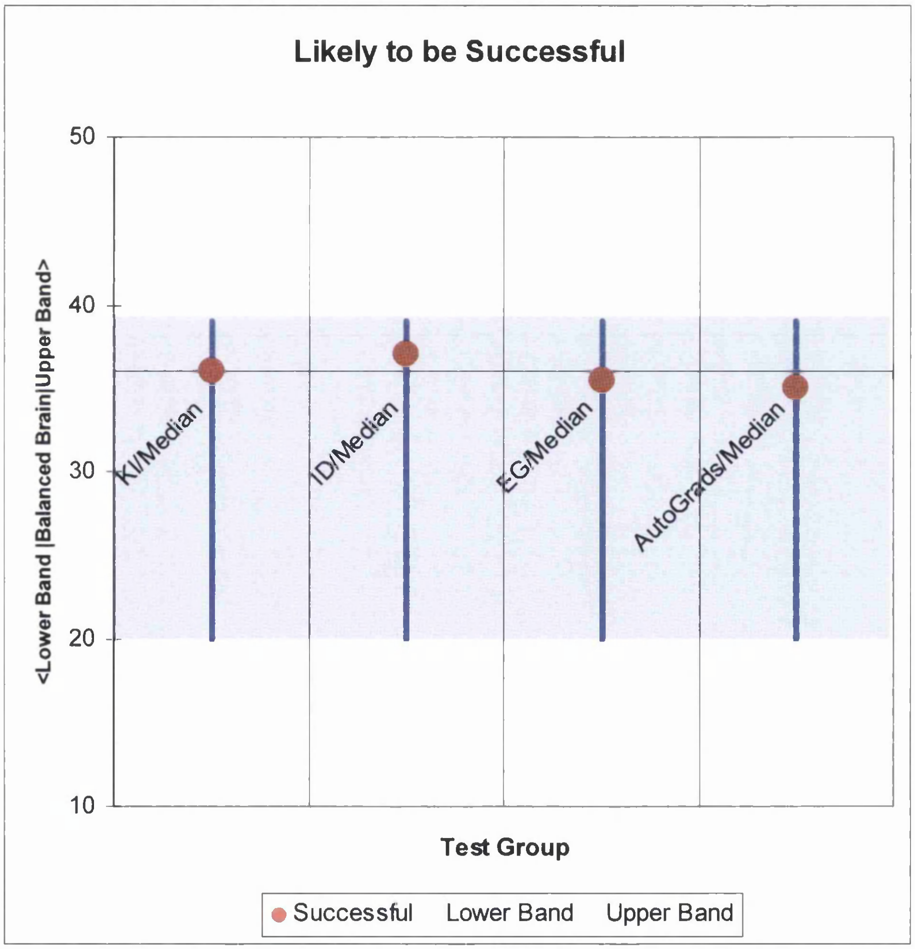


Figure 8.48 Mapping Median Data for 'Likely to be Successful' against Carter and Russell's Personality Bands

Here the data, whilst in the mid range, presents a picture of hard-working individuals of strong character who tend to serve the interest of others above self. They are persistent, ambitious and show flair and imagination. With all the median data falling in the mid-range band they may be hard working but this may be tempered by self-doubt. The data presents a relatively uniform picture across the four groups with Industrial Design graduates returning the highest scores. With no clear-cut differentiation between the groups there is little to be gleaned from the results in terms of propensity towards innovativeness other than that all the groups are hard working and embrace change.

8.7.3 Personality Analysis of 'Imaginative Thinking' Trait

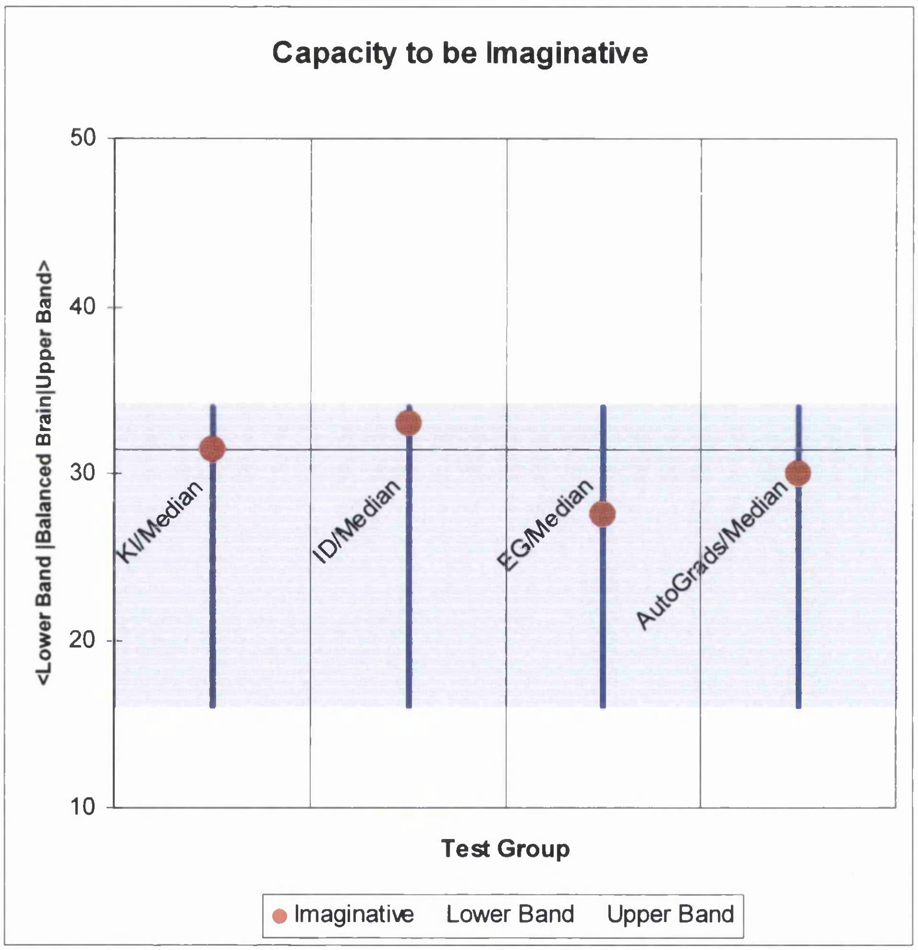


Figure 8.49 Mapping Median Data for 'Capacity for Imaginative Thinking' against Carter and Russell's Personality Bands

The data indicates a difference in the responses given by the Engineering graduates and the Automotive Designers to those recorded by the Industrial Design graduates. Generally the results for the former indicate their mindset is more conventional and respectable. Results for the latter group indicate they are more open minded and unconventional in some aspects of life. The data for Industrial Designers and Known

Innovators indicate they are highly imaginative and unconventional. The results for Industrial Design are bordering on the upper band of responses indicating they are inventive and free-thinking individuals, inclined to be frustrated and dissatisfied. This gives a clear indication that they have a greater propensity for innovation than the other two graduate groups.

8.7.4 Personality Analysis of 'Risk Taking' Trait

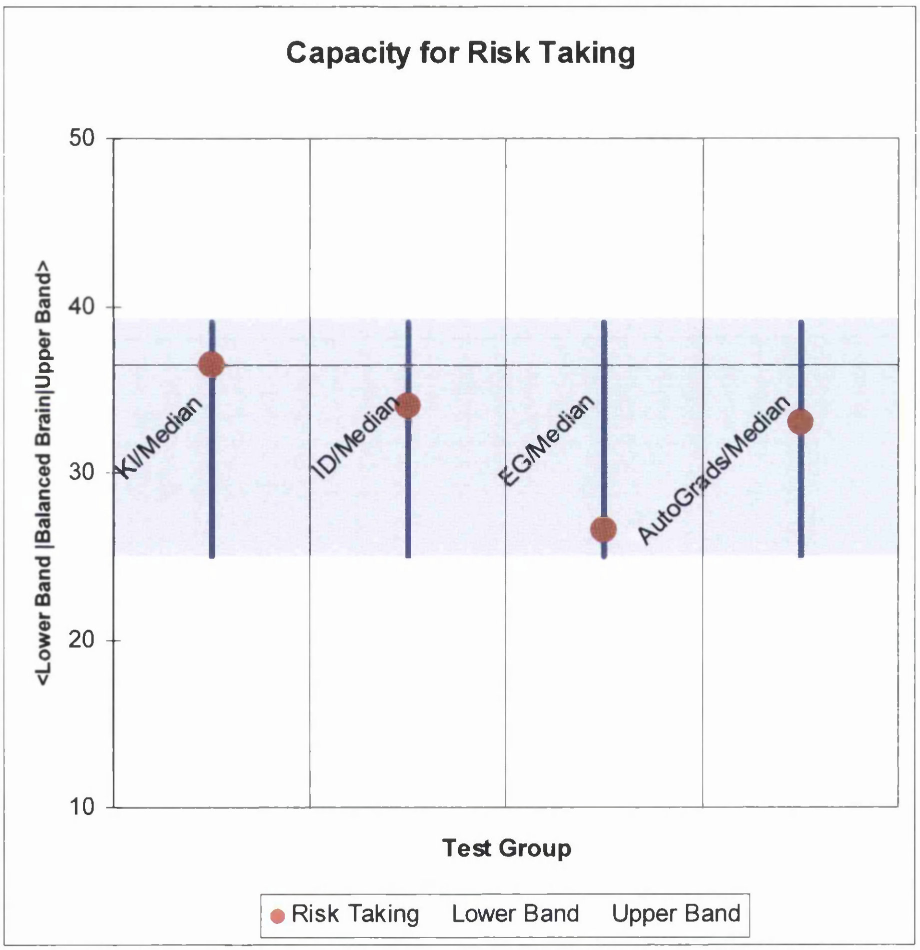


Figure 8.50 Mapping Median Data for 'Capacity for Risk Taking' against Carter and Russell's Personality Bands

Risk taking provides us with a greater spread of results than seen in any other trait test. Generally, the responses for Known Innovators, Industrial Designers and Automotive Designers indicate a balanced approach to risk. Respondents are not averse to taking the occasional risk but in a measured and calculated manner. Here the score for Known Innovators indicates a far more aggressive attitude to risk which can in some instances border on the reckless when viewed from the outside. Engineering graduates demonstrate a very conservative attitude to risk. Their results indicate they are steady and sensible, not likely to take risks. This corresponds to the laterality score for this group which indicated they tended toward left-hemispherical dominance. This manifests itself in an analytical and logical approach which can undermine risk taking.

8.7.5 Personality Analysis of 'Self-Confidence' Trait

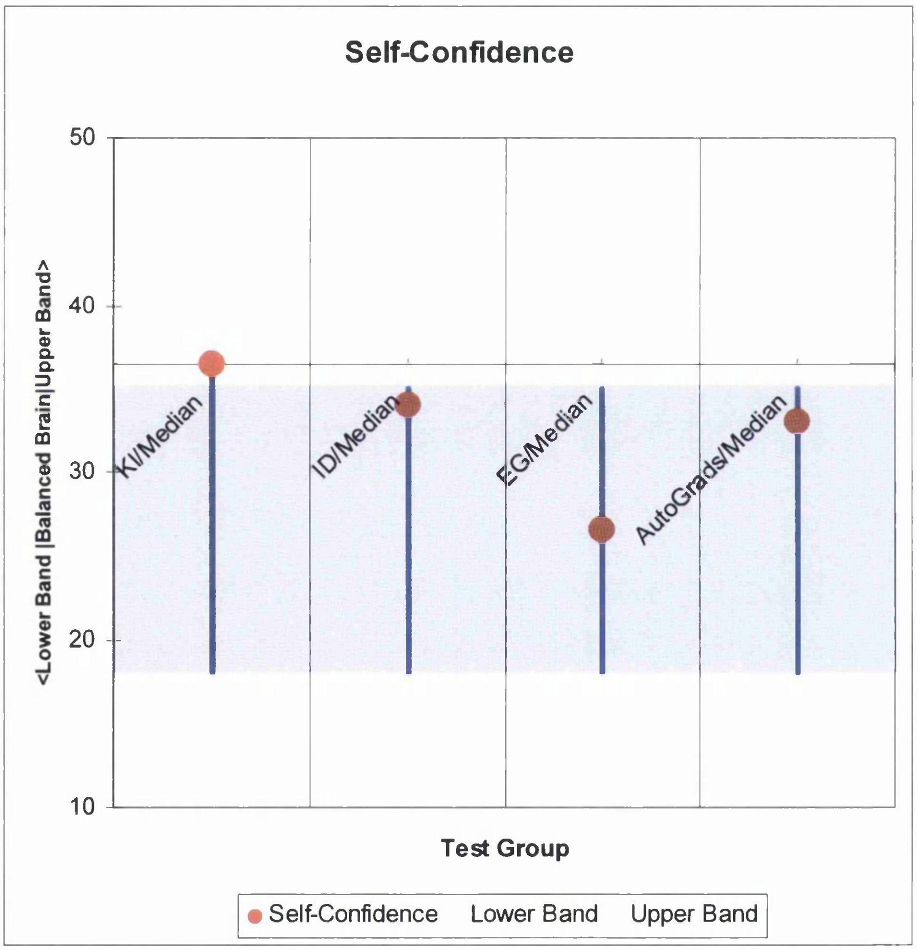


Figure 8.51 Mapping Median Data for 'Self-Confidence' against Carter and Russell's Personality Bands

This particular personality trait offers us a significant insight into the make up of the innovative mind. The data for Known Innovators are firmly rooted in the upper band of likely responses and demonstrate a significant degree of difference between them and the other three groups. The results show them to be very confident, to have a positive personality and to be immensely assured and self-reliant. The responses recorded by the Industrial Design group come closest to emulating the Known Innovator group. Their results show they are inclined to embrace change in the workplace as a way of self-advancement. They are quietly confident whilst being careful not to be over-confident. The Automotive Designers demonstrate many of the same personality traits but are inclined to take more measured risks and prefer security without taking too many chances. Both design groups tested show that they are inclined to weigh up the options before taking decisions. The Engineering graduates tested do show many of the characteristics of self-confidence but are inclined to seek confirmation and affirmation rather than relying on their own intuition.

8.8 *Proposed Innovation Trait Index*

By examining the results of the innovation trait questionnaire the author proposes a novel Innovation Trait Index (ITI). The index will serve as a measure of the likely propensity of individuals towards innovativeness in the context of industrial design practice.

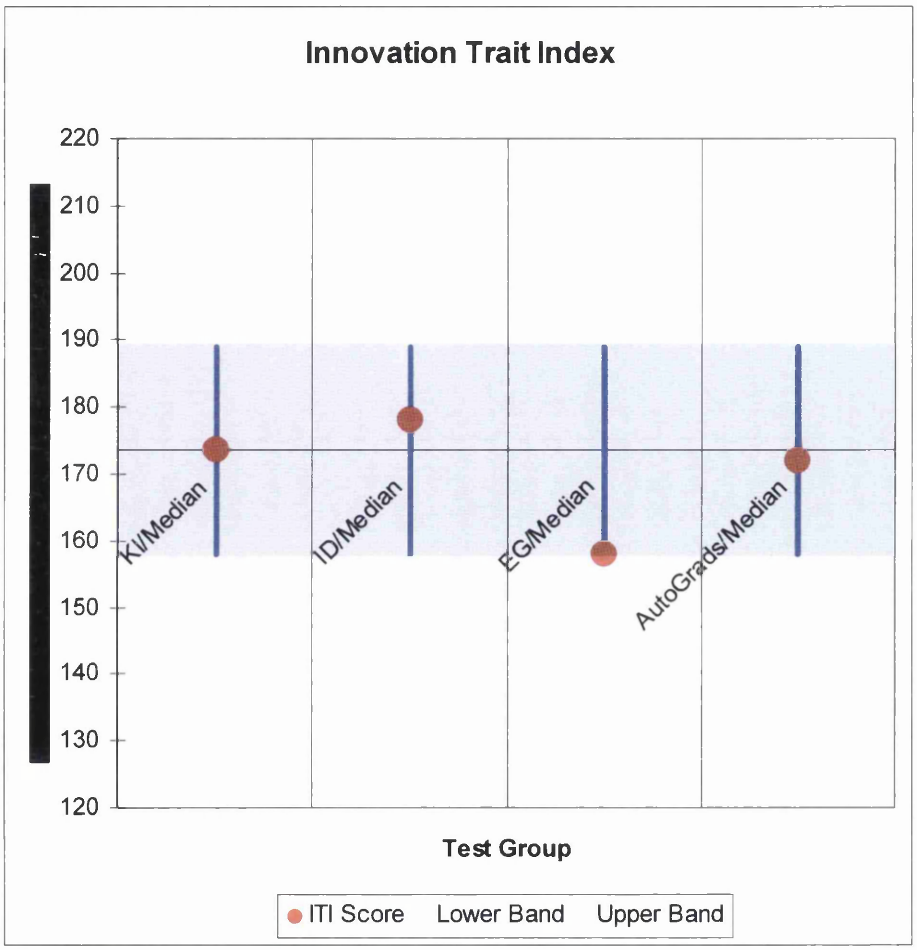


Figure 8.52 Median Innovation Trait Index Scores

Taking the median data for Known Innovators as our benchmark and the standard deviation of 15.35 we create a value range of 0-157 158-189 and 190-200 corresponding to the lower, mid and upper bands of our Innovation Trait Index.

Innovation Trait Index				
Lower Band	L	Mid Band	U	Upper Band
0-157		158-189		190-250
Non-Innovators		**Measured Innovators**		**High Risk Innovators**
Sentimental and not particularly interested in moving forward. Resistant to new technology. Not ambitious. Shuns responsibility in work life. Prefers home and family life to career progression. Lacking self-confidence. Self-deprecating. Overly modest. Nervous in the company of others. Not particularly imaginative. Not driven to be new or original. Steady and sensible. Not likely to take risks.		Forward looking but respectful of tradition. Excited by future opportunities and new technology. Ambitious and hard working but troubled by bouts of self-doubt. Tends to serve the interest of others above self. Quietly confident positive attitude. Assured and self-reliant but careful not to be over-confident. Inclined to embrace change in the workplace as a way of self-advancement. Generally conventional and respectable but open minded and unconventional in some aspects of life. Can be frustrated with the status quo.		Continually planning for the future. Philosophy is to continually move forward. Ambitious, hard working and persistent with strong character. Flair and imagination. Very confident. Assured and self-reliant. Accepting of change. Inclined to embrace change in the workplace as a way of self-advancement. Highly imaginative. Unconventional. Can be frustrated and dissatisfied. Inventive and free thinking. A risk taker but can be inclined to

		Inventive and free thinking. Measured and calculated risk taker who takes a balanced approach to risk management.		recklessness. At the higher end can be prone to gambling rather than calculating.
Not natural innovators. Not given to innovativeness in the workplace. May be highly creative or logical but lack the necessary ability to deliver or reduce to practice.		Natural innovators. At the lower end they may need to be encouraged to follow their innovative instincts. At the upper end they are self-confident innovators who actively seek out the new.		Highly innovative in all aspects of life. These are innovators motivated by the need to change and progress but can be inclined to ignore rather than calculate risk.

Figure 8.53 Personality analysis of 'Innovation Trait Index' (Author)

8.9 Summary and Review of Outcomes

This chapter set out to demonstrate the extent to which the propensity for innovation differed in industrial design graduates relative to comparable graduates in automotive design and engineering. The innovativeness trait inventory was established through the work of an expert panel and tested on a group of known innovators. The outcome has been fourfold:

1. An innovativeness trait inventory has been devised
2. The impact of left/right hemispherical dominance has been quantified
3. An Innovation Trait Index has been developed and tested
4. The degree to which the propensity for innovation differs between graduates of industrial design, automotive design and engineering has been evaluated

Of the three questions raised in 7.15 we have successfully answered the third,

To what extent does a graduate from the industrial design programme demonstrate a propensity for innovation compared to graduates from other programmes and known innovators?

The answer is defined by the ITI and its subsequent analysis. The median results from the psychometric tests underpinning the ITI show that graduate industrial designers from the Swansea programme have a higher propensity to innovate than graduates of comparable programmes. Their responses demonstrate them to be highly innovative in all aspects of life. At the upper end of the mid band they are self-confident innovators who actively seek out the new. However, there is a note of caution to be struck. The median may fall within the upper half of the mid band but a number of respondents fell in the upper band. These remain innovators motivated by the need to change and progress but can be inclined to ignore rather than calculate risk. The index tells us that successful innovators need to be able to take measured risks with a balanced view of the 'big picture' and necessary details to enable an innovation to be implemented.

Chapter 9 considers the application of the ITI to identify change in the propensity for innovation of undergraduates studying industrial design at Swansea Institute. Only by mapping any change in propensity can we identify whether there is a correlation between that change and the phases of the programme.

9 Measuring Change in Innovation Propensity

"It's only the future if it can't be made."

(Ross Lovegrove, 2001)

9.1 Introduction

7.15 raised three questions. One has been answered in Chapter 8. Here we consider the remaining two:

1. *Can the effect of the programme of study on the individual's propensity to innovate be quantified?*
2. *What is the effect on the individual of studying under the industrial design innovation model presented here compared with students studying on a more traditional design programme?*

The chapter considers both questions in parallel, outlines the methodology by which they are answered and presents the data resulting from the investigation. The following flow chart (Figure 9. 1) indicates the methodology for data collection and analysis.

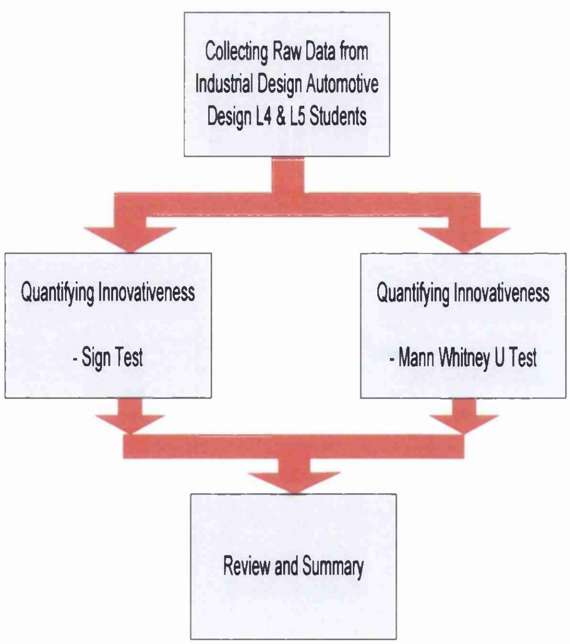


Figure 9. 1 Test Methodology for Identifying Change in Innovation Propensity

9.2 Test Methodology

Over a two-year period, data was collected in the form of responses to the psychometric test developed in Chapter 8. Students studying on the undergraduate programmes in Industrial Design and Automotive Design were tested. Level 4 students were tested in October/November of their first term. Level 5 students were tested in June/July at the end of their sixth term. The tests were conducted under controlled conditions in a computer studio. Students were briefed to ensure there was common understanding of the requirements and given guidance on expected time for completion. The time factor is important in so far as it was important for students to give an instinctive response to the questions rather than a calculated and contrived response.

9.3 Raw Psychometric Data

Data captured at the conclusion of the tests was collated and tabulated (Appendices 6-9). The results were then analysed to ascertain if any patterns were apparent. The following tables (Figures 9.2 and 9.3) summarise the initial outcomes gleaned from the data. Before we consider the data in detail, a number of points of interest are evident in the data. Firstly, as can be seen from the full tables in the appendices, the sample groups are unequal in size and do not necessarily follow through from Level 4 to Level 5. Secondly, in the case of the industrial design students the degree of variation in the group diminishes as they move from one level to the next. In the case of automotive design, the variation increases. Students leaving the programme or not being available for repeat tests may explain this. Thirdly, it is important to note the difference between the mean and median scores for each factor. Typically, the difference is ± 1 but can be as much as 2. This difference can be explained by the pattern of distribution. A small number of instances at either the high or the low ends of the distribution can distort the mean value but has less of an effect on the median value. This can be seen from the following graphs which map the distribution of test results for innovation against those for left/right hemisphere dominance (Figure 9. 4, Figure 9. 5, Figure 9. 7).

Industrial Design												
	Mean for Each Group			Standard Deviation for Each Group			Median for each group			Median - Mean		
	1st Test	2nd Test	ID Graduates	1st Test	2nd Test	ID Graduates	1st Test	2nd Test	ID Graduates	1st Test	2nd Test	ID Graduates
Laterality	36.3	38.3	42.0	5.0	4.8	5.7	36	39	42	0	0	0
	Level 4	Level 5	Level 6	Level 4	Level 5	Level 6	Level 4	Level 5	Level 6	Level 4	Level 5	Level 6
Forward Looking	31.2	32.0	37.6	4.8	3.9	1.9	33	32	38	1	0	0
Successful	31.1	32.1	36.1	4.5	5.3	3.0	31	33	37	-1	0	1
Imaginative	29.1	29.3	32.8	3.8	3.2	2.9	30	29	33	1	0	0
Risk Taking	32.9	34.1	34.0	5.7	5.4	3.8	33	35	34	0	0	0
Confidence	33.3	34.0	37.1	5.0	4.7	2.1	35	33	37	2	-1	0
Total	157.8	161.6	177.5	18.4	15.8	10.7	161	161	178	3	-1	1

Figure 9. 2 Summary Data for L4 & L5 Industrial Design

Automotive Design												
	Mean for Each Group			Standard Deviation for Each Group			Median for each group			Median - Mean		
	1st Test	2nd Test	Auto Graduates	1st Test	2nd Test	Auto Graduates	1st Test	2nd Test	Auto Graduates	1st Test	2nd Test	Auto Graduates
Laterality	36.0	37.4	38.9	4.7	5.0	4.4	36	37	40	0	0	1
	Level 4	Level 5	Level 6	Level 4	Level 5	Level 6	Level 4	Level 5	Level 6	Level 4	Level 5	Level 6
Forward Looking	31.3	31.9	33.1	3.9	3.2	7.1	32	32	35	1	0	2
Successful	33.8	34.0	35.6	4.2	5.3	5.8	33	35	35	-1	1	-1
Imaginative	28.7	28.7	31.3	4.2	4.1	3.6	29	29	30	0	0	-1
Risk Taking	34.0	32.9	33.8	5.9	5.1	3.1	36	33	33	2	0	-1
Confidence	36.2	35.5	35.3	3.6	5.3	6.5	36	37	36	0	2	1
Total	163.9	162.9	169.4	10.8	12.9	17.6	164	167	172	0	4	3

Figure 9. 3 Summary Data for L4 & L5 Automotive Design

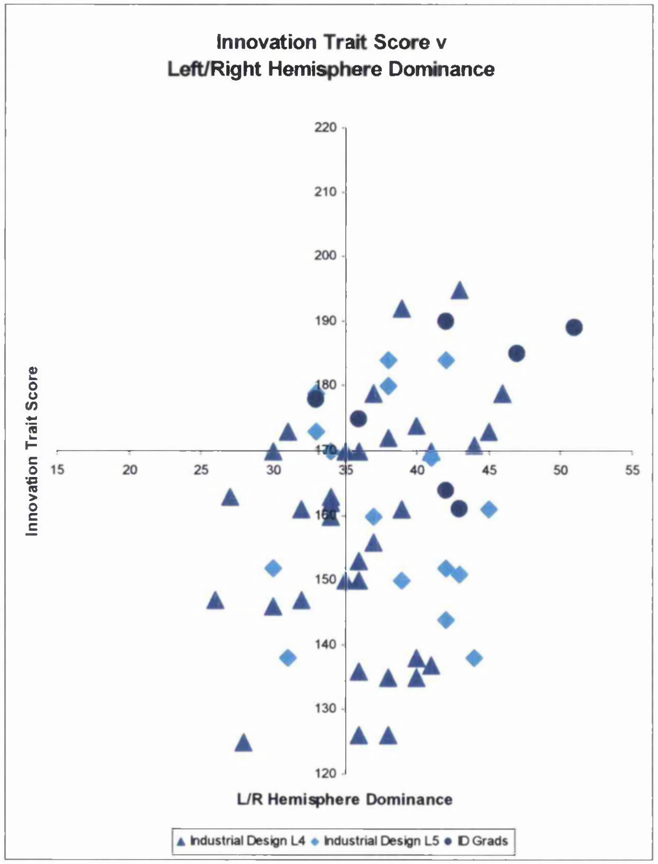


Figure 9. 4 Innovation Trait Score vs. Laterality for Industrial Designers

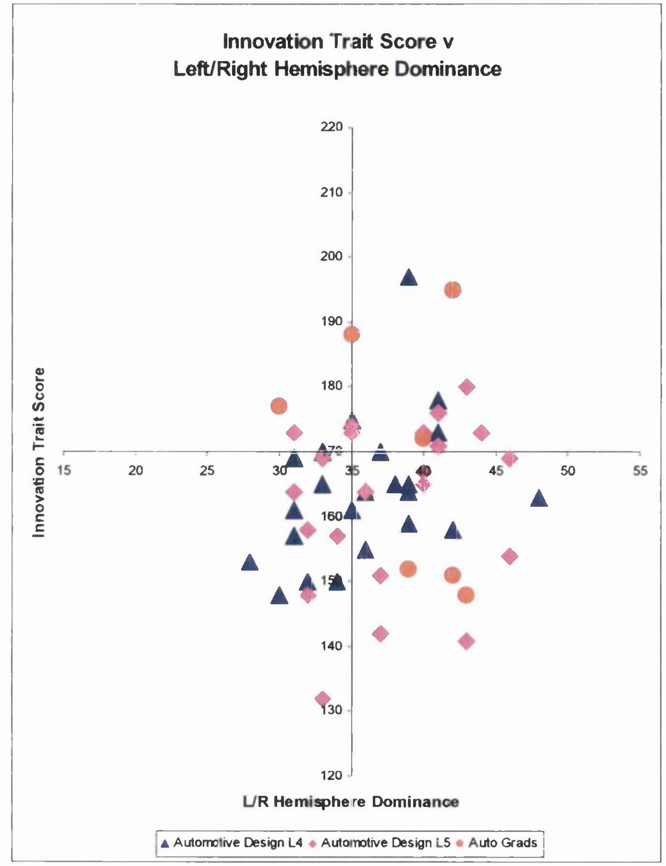


Figure 9. 5 Innovation Trait Score vs. Laterality for Automotive Designers

We now compare the median data for each group against those for Known Innovators and Engineering graduates. The data extracted from the main data set is summarised below.

		L4	L5	Graduates
ID	Laterality	36	38.5	42
	ITI	161	160.5	178
Auto	Laterality	36	37	40
	ITI	164	167	172
KI	Laterality	-	-	35
	ITI	-	-	173.5
EG	Laterality	-	-	29.5
	ITI	-	-	158

Figure 9. 6 Median Data from Main Data Set

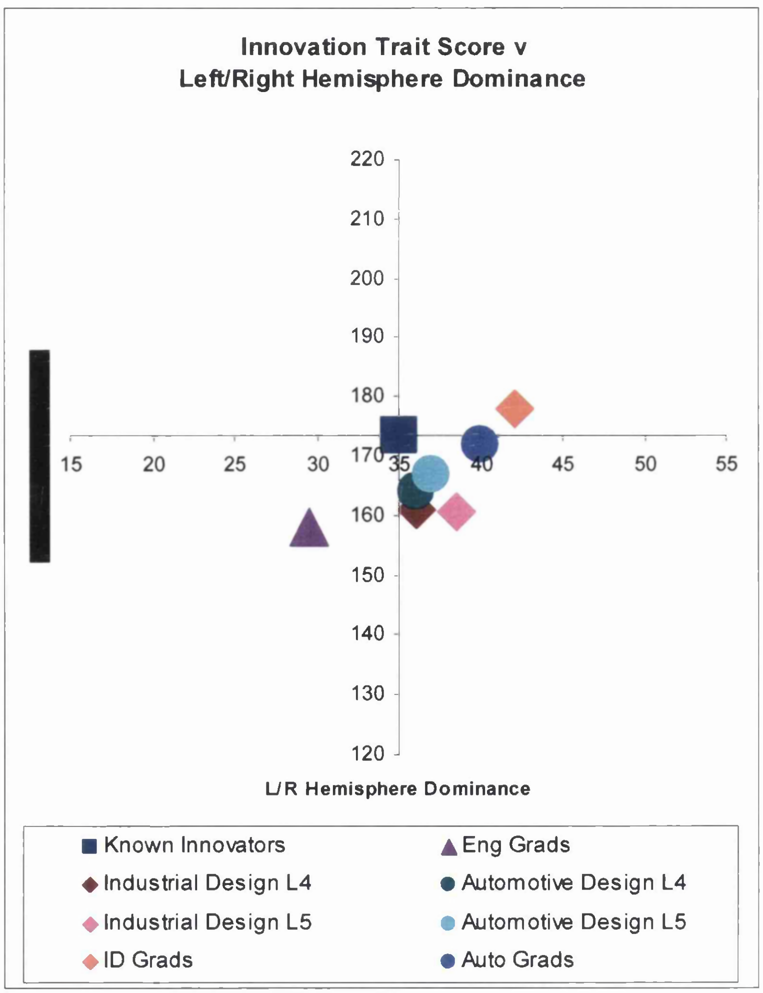


Figure 9. 7 Comparing Median Undergraduate ITI Scores Against Graduates and Known Innovators

Initial observations indicate a negative change in innovativeness for industrial design between level 4 and level 5. The automotive design students demonstrate a positive change during the same period. However, it is in the transition from level 5 to 6 that the potentially significant change takes place. Both groups of designers present increases in overall ITI scores. To obtain a more accurate measure of the change in ITI score we refine the data set to include only those who completed both the initial L4 test and the follow-up L5 test. From the data we see that fourteen Industrial Design and nine Automotive Design students completed paired tests.

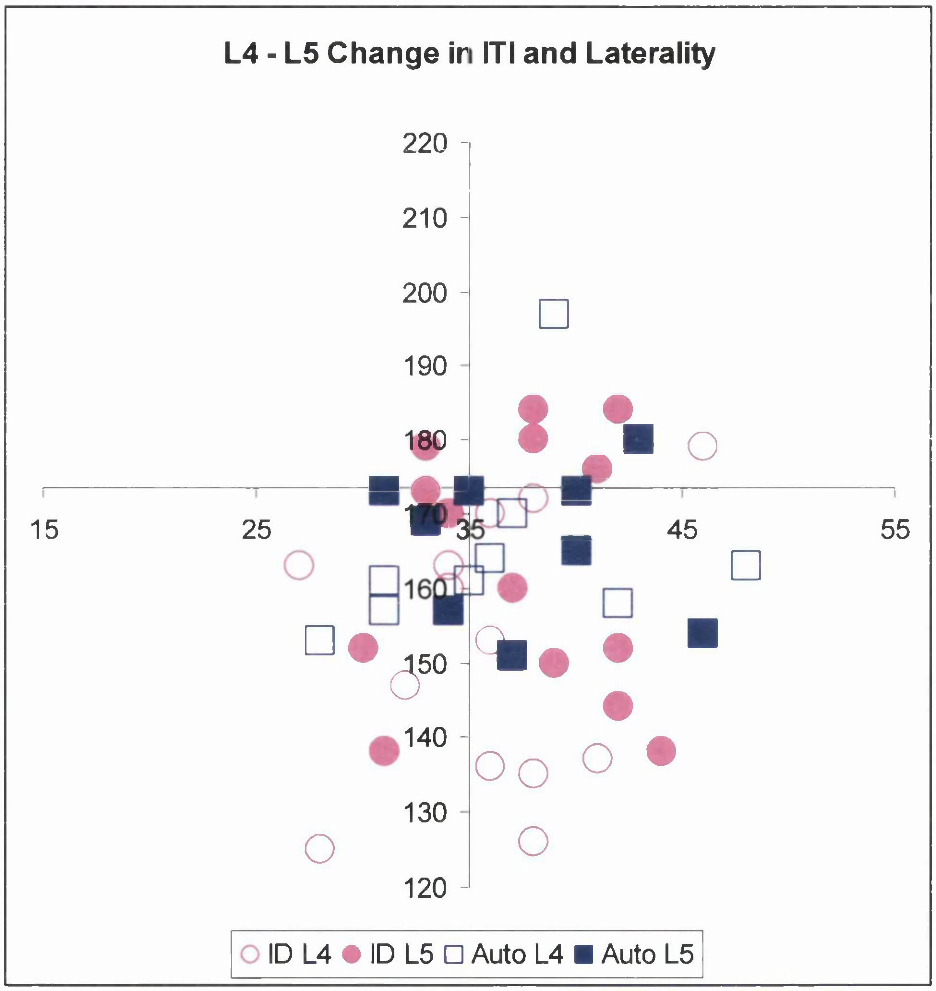


Figure 9. 8 Change in ITI/Laterality for L4 and L5

9.4 Nonparametric Test for Change in Innovativeness

The question is how significant are these changes and what has changed at the detailed level to bring the change about? We now use two nonparametric tests to quantify the apparent changes in student personality traits:

- Sign Test
- Mann-Whitney *U* Test

9.4.1 The Sign Test

Nonparametric tests are particularly valuable in dealing with non-numerical data such as that derived from this psychometric test – the Innovation Trait Index where individuals rank or score their response to questions in order of preference. Before conducting the tests, the data was analysed to identify paired tests i.e. instances where students took both the initial test in level 4 and the follow-up test at the end of level 5. This negates the impact of students who withdrew or missed the follow-up test.

With the data set established, we now state our hypothesis. The null hypothesis (*Ho*) is that there is no difference between the pairs. We wish to test the hypothesis *Ho* that there is no difference between the first and second test in terms of the level of propensity towards innovation, i.e. the observed differences between the scores are merely the result of chance, which is to say the tests came from the same population. The alternative hypothesis (*Ha*) is that there is a difference at the 0.05 significance level.

A simple nonparametric test in the case of such paired samples is provided by the sign test. The test consists of taking the difference between the scores for each year group (level 4 and level 5) and writing on the *sign* of the difference (i.e. plus or minus).

	Laterality		Forward Looking		Successful		Imaginative		Risk Taking		Confidence		ITI Score	
	L4	L5	L4	L5	L4	L5	L4	L5	L4	L5	L4	L5	L4	L5
Industrial Design Students														
ID001	34	37	33	34	35	29	30	31	33	35	32	31	163	160
ID002	27	34	30	29	34	36	30	32	32	34	37	39	163	170
ID003	36	30	24	30	34	35	27	28	23	29	28	30	136	152
ID004	34	44	33	27	28	21	29	29	37	33	33	28	160	138
ID005	38	41	31	34	36	35	34	34	30	31	41	42	172	176
ID006	28	31	27	28	25	28	24	24	24	27	25	31	125	138
ID007	38	42	23	25	21	32	28	25	32	34	22	28	126	144
ID008	46	42	34	38	33	33	36	33	39	40	37	40	179	184
ID009	36	33	26	33	27	35	30	29	33	41	37	41	153	179
ID010	32	33	31	34	29	39	25	27	33	40	29	33	147	173
ID011	38	42	27	29	28	35	26	27	26	28	28	33	135	152
ID012	36	38	29	32	38	39	30	33	37	37	36	39	170	180
ID013	41	39	25	32	30	31	26	25	26	30	30	32	137	150
ID014	31	38	36	39	33	37	34	33	34	37	36	38	173	184
Median	36	38	29.5	32	31.5	35	29.5	29	32.5	34	32.5	33	157	165

Figure 9. 9 Paired Data for Industrial Design Students

	ITI Score		Laterality		Forward Looking		Successful		Imaginative		Risk Taking		Confidence	
	Difference L5 - L4 total		Diff		Diff		Diff		Diff		Diff		Diff	
ID001	-3	minus	3	plus	1	plus	-6		1	plus	2	plus	-1	
ID002	7	plus	7	plus	-1		2	plus	2	plus	2	plus	2	plus
ID003	16	plus	-6		6	plus	1	plus	1	plus	6	plus	2	plus
ID004	-22	minus	10	plus	-6		-7		0		-4		-5	
ID005	4	plus	3	plus	3	plus	-1		0		1	plus	1	plus
ID006	13	plus	3	plus	1	plus	3	plus	0		3	plus	6	plus
ID007	18	plus	4	plus	2	plus	11	plus	-3		2	plus	6	plus
ID008	5	plus	-4		4	plus	0		-3		1	plus	3	plus
ID009	26	plus	-3		7	plus	8	plus	-1		8	plus	4	plus
ID010	26	plus	1	plus	3	plus	10	plus	2	plus	7	plus	4	plus
ID011	17	plus	4	plus	2	plus	7	plus	1	plus	2	plus	5	plus
ID012	10	plus	2	plus	3	plus	1	plus	3	plus	0		3	plus
ID013	13	plus	-2		7	plus	1	plus	-1		4	plus	2	plus
ID014	11	plus	7	plus	3	plus	4	plus	-1		3	plus	2	plus
test statistic (*x*)		**12**		**10**		**12**		**10**		**6**		**12**		**12**
sample size (*n*)		**14**		**14**		**14**		**14**		**14**		**14**		**14**
p-value		**0.007**		**0.09**		**0.007**		**0.09**		**0.876**		**0.007**		**0.007**

Figure 9. 10 Sign Data for Industrial Design Students

9.4.2 Signed Test Analysis for Industrial Design Students

Referring to Figure 9. 9 to test the hypothesis *Ho* that there is no difference between level 4 and 5 against the alternative hypothesis *Ha* that there is a difference at the 0.05 significance level we analyse the paired data thus:

	x	n	p-value*		
ITI	12	14	0.007	$< \acute{\alpha}$	**reject *Ho***
Laterality	10	14	0.09	$> \acute{\alpha}$	can't reject
Forward Looking	12	14	0.007	$< \acute{\alpha}$	**reject *Ho***
Successful	10	14	0.09	$> \acute{\alpha}$	can't reject
Imaginative	6	14	0.876	$> \acute{\alpha}$	can't reject
Risk Taking	12	14	0.007	$< \acute{\alpha}$	**reject *Ho***
Confidence	12	14	0.007	$< \acute{\alpha}$	**reject *Ho***

*** Using binomial table** (Appendix 10)

Figure 9. 11 Sign Test Data for Industrial Design Students

The results are not unequivocal but they do indicate a rejection of hypothesis *Ho*. Three out of five innovation traits show significant difference from level 4 to level 5 and the overall ITI score also indicates significant difference. The implications of this test are that there appears to be a significant change in the propensity for innovation for students studying industrial design on Phase 3 of the Swansea Institute programme. We have to accept the alternative hypothesis *Ha* that there is a difference at the 0.05 significance level. To confirm whether or not this is specific to industrial design we now evaluate the data for the automotive design programme.

	Laterality		Forward Looking		Successful		Imaginative		Risk Taking		Confidence		ITI Score	
	L4	L5	L4	L5	L4	L5	L4	L5	L4	L5	L4	L5	L4	L5
Automotive Design Students														
Auto001	31	35	33	35	30	37	22	27	38	33	38	41	161	173
Auto002	36	37	29	28	31	31	36	29	38	31	30	32	164	151
Auto003	35	40	25	31	29	36	33	36	36	34	38	36	161	173
Auto004	28	34	27	32	36	34	26	24	29	29	35	38	153	157
Auto005	37	31	33	36	38	45	32	28	32	26	35	38	170	173
Auto006	31	46	32	30	38	35	26	22	25	28	36	39	157	154
Auto007	39	33	37	29	42	36	28	25	46	44	44	35	197	169
Auto008	48	43	33	38	29	29	30	35	40	38	31	40	163	180
Auto009	42	40	32	32	33	32	23	25	32	34	38	42	158	165
Median	36	37	32	32	33	35	28	27	36	33	36	38	161	169

Figure 9. 12 Paired Data for Automotive Design Students

	ITI Score		Laterality		Forward Looking		Successful		Imaginative		Risk Taking		Confidence	
	Difference L5 - L4 total		Diff		Diff		Diff		Diff		Diff		Diff	
Auto001	12	plus	4	plus	2	plus	7	plus	5	plus	-5		3	plus
Auto002	-13		1	plus	-1		0		-7		-7		2	plus
Auto003	12	plus	5	plus	6	plus	7	plus	3	plus	-2		-2	
Auto004	4	plus	6	plus	5		-2		-2		0		3	plus
Auto005	3	plus	-6		3	plus	7	plus	-4		-6		3	plus
Auto006	-3		15	plus	-2		-3		-4		3	plus	3	plus
Auto007	-28		-6		-8		-6		-3		-2		-9	
Auto008	17	plus	-5		5	plus	0		5	plus	-2		9	plus
Auto009	7	plus	-2		0		-1		2	plus	2	plus	4	plus
test statistic (*x*)		**6**		**5**		**4**		**3**		**4**		**2**		**7**
sample size (*n*)		**9**		**9**		**9**		**9**		**9**		**9**		**9**
p-value		**0.254**		**0.5**		**0.746**		**0.91**		**0.746**		**0.98**		**0.09**

Figure 9. 13 Sign Data for Automotive Design Students

9.4.3 Sign Test Analysis for Automotive Design Students

Referring to Figure 9. 13 to test the hypothesis *Ho* that there is no difference between level 4 and 5 against the alternative hypothesis *Ha* that there is a difference at the 0.05 significance level we use the same formula as for industrial design. The results are recorded below.

	x	n	p-value*		
ITI	6	9	0.254	> ά	can't reject
Laterality	5	9	0.5	> ά	can't reject
Forward Looking	4	9	0.746	> ά	can't reject
Successful	3	9	0.091	> ά	can't reject
Imaginative	4	9	0.746	> ά	can't reject
Risk Taking	2	9	0.98	> ά	can't reject
Confidence	7	9	0.09	> ά	can't reject

*** Using binomial table** (Appendix 10)

Figure 9. 14 Sign Test Data for Automotive Design Students

The results for automotive design are unequivocal in that they cannot reject the hypothesis *Ho*. None of the innovation traits shows any significant change from level 4 to level 5. The results of this test provide confidence of significant difference between the development of Industrial Design undergraduates and those studying Automotive Design. Whereas the results for Industrial Design presented evidence of difference between the levels of study, the Automotive Design results provide no such indication.

9.5 *Mann-Whitney U Test*

The Mann-Whitney U Test is an alternative statistical test which measures the degree of intermingling in the combined rank ordering of two groups of data. We apply this test to determine the significance of the difference observed in the following two cases:

- Industrial Design Students vs. Known Innovators
- Industrial Design Students vs. Automotive Design Students

9.5.1 Analysis of Industrial Design Students vs. Known Innovators

Figure 9. 16 presents the data table and results of a Mann-Whitney U test for two groups of data: Known Innovators and L4 & L5 Industrial Design Students. As one would expect, results for the Known Innovator group are significantly different from results evident from the L4 (year 1) group of Industrial Design students. That is to say, the z statistic is greater or equal to -1.96 or greater or equal to +1.96. Of the five innovation traits that comprise our Innovation Trait Index, only 'Imaginative' shows no significant difference between the two groups. This is interesting, as it also emerges from the test that there is no significant difference in 'Laterality'. Taken together these two traits may indicate that both Known Innovators and Industrial Designers share a common perspective and approach to problem solving. That aside, it is clear from the test results for both U and z that there is significant difference at this stage of the industrial designers' development.

The second year or Level 5 results show a quite different picture. Analysing the L5 data from the Industrial Design group against the data for Known Innovators shows that there has been a shift in the degree of intermingling of data. Of the five traits, four now show no significant difference between the two groups. Only in the case of 'Forward Looking' does there remain a significant difference. The change in relationship between the two groups is clear from the results for the overall ITI score. This is indicative that a change has occurred in the mindset of the ID students. The analysis demonstrates that by the end of Level 5 (year 2) they exhibit the necessary traits, which would indicate that their propensity to be innovators has increased.

	Laterality				Forward Looking				Successful				Imaginative				Risk Taking				Confidence				Total			
	L4		L5		L4		L5		L4		L5		L4		L5		L4		L5		L4		L5		L4		L5	
		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk
ID001	34	12	37	15	33	12	34	12.5	35	18.5	29	5.5	30	15.5	31	15.5	33	11.5	35	15	32	8	31	4.5	163	12	160	9
ID002	27	1	34	12	30	8	29	4.5	34	16	36	18	30	15.5	32	18.5	32	8.5	34	11.5	37	19.5	39	19.5	163	12	170	12.5
ID003	36	16	30	3	24	2	30	6	34	16	35	15	27	8	28	9	23	2	29	4	28	3.5	30	3	136	4	152	5.5
ID004	34	9	44	23	33	11.5	27	2	28	5.5	21	1	29	9	29	9.5	37	16.5	33	7.5	33	9	28	1.5	160	9	138	1.5
ID005	38	17	41	17	31	9.5	34	11.5	36	17	35	12.5	34	19.5	34	21	30	5	31	5.5	41	21.5	42	22	172	15.5	176	15
ID006	28	2	31	5.5	27	5.5	28	3	25	2	28	3	24	2.5	24	2.5	24	3	27	2	25	2	31	4.5	125	1	138	1.5
ID007	38	21	42	24	23	1	25	1	21	1	32	9	28	9	25	4.5	32	8.5	34	11.5	22	1	28	1.5	126	2	144	3
ID008	46	28	42	24	34	14.5	38	21.5	33	13	33	10.5	36	27	33	22.5	39	24.5	40	24.5	37	19.5	40	22	179	23	184	23.5
ID009	36	16	33	9.5	26	4	33	9.5	27	3	35	15	30	15.5	29	12	33	11.5	41	27	37	19.5	41	24.5	153	7	179	20
ID010	32	9	33	9.5	31	9.5	34	12.5	29	8.5	39	24	25	4	27	7.5	33	11.5	40	24.5	29	5	33	9.5	147	6	173	15.5
ID011	38	21	42	24	27	5.5	29	4.5	28	5.5	35	15	26	6	27	7.5	26	4.5	28	3	28	3.5	33	9.5	135	3	152	5.5
ID012	36	16	38	18	29	7	32	7.5	38	23.5	39	24	30	15.5	33	22.5	37	19.5	37	17.5	36	16	39	19.5	170	15.5	180	21.5
ID013	41	25	39	21	25	3	32	7.5	30	10	31	7.5	26	6	25	4.5	26	4.5	30	5	30	6	32	7	137	5	150	4
ID014	31	6.5	38	18	36	19.5	39	23	33	13	37	20	34	24	33	22.5	34	15	37	17.5	36	16	38	17.5	173	19.5	184	23.5
KI001	32	9	32	7.5	34	14.5	34	12.5	38	23.5	38	22	26	6	26	6	35	17.5	35	15	37	19.5	37	16	170	15.5	170	12.5
KI002	30	4.5	30	3	35	16	35	15	46	28	46	28	39	28	39	28	43	28	43	28	36	16	36	15	199	27	199	27
KI003	29	3	29	1	38	23	38	21.5	37	21.5	37	20	32	20	32	18.5	38	22	38	20	35	12.5	35	12.5	180	24	180	21.5
KI004	34	12	34	12	36	19.5	36	18	29	8.5	29	5.5	29	11.5	29	12	35	17.5	35	15	35	12.5	35	12.5	164	14	164	11
KI005	38	21	38	18	36	19.5	36	18	28	5.5	28	3	29	11.5	29	12	40	26.5	40	24.5	41	25.5	41	24.5	174	21	174	17
KI006	38	21	38	18	36	19.5	36	18	31	11	31	7.5	32	20	32	18.5	38	22	38	20	35	12.5	35	12.5	172	17.5	172	14
KI007	43	27	43	27	42	27	42	27	37	21.5	37	20	31	18	31	15.5	33	11.5	33	8.5	35	12.5	35	12.5	178	22	178	19
KI008	36	16	36	14	36	19.5	36	18	28	5.5	28	3	32	20	32	18.5	31	7	31	6.5	32	8	32	7	159	8.5	159	7.5
KI009	43	27	43	27	47	28	47	28	44	26.5	44	26.5	35	26	35	27	40	26.5	40	24.5	44	28	44	28	210	28	210	28
KI010	39	24	39	21	41	26	41	26	39	25	39	24	33	22	33	22.5	39	24.5	39	22	40	23.5	40	22	192	26	192	26
KI011	32	9	32	7.5	33	12	33	9.5	34	16	34	12	22	1	22	1	34	15	34	11.5	40	23.5	40	22	163	12	163	10
KI012	30	4.5	30	3	40	24.5	40	24.5	33	13	33	10.5	24	2.5	24	2.5	38	22	38	20	38	22	38	17.5	173	19.5	173	15.5
KI013	31	6.5	31	5.5	40	24.5	40	24.5	44	26.5	44	26.5	29	11.5	29	12	34	15	34	11.5	42	27	42	26.5	189	25	189	25
KI014	36	16	36	14	36	19.5	36	18	35	18.5	35	15	34	24	34	25.5	22	1	22	1	32	8	32	7	159	8.5	159	7.5

Figure 9. 15 Data set for Mann-Whitney Test

t-statistic (Rank Sum of the smaller group)	*200*	*222*	*113*	*127*	*153*	*180*	*177*	*179.5*	*146*	*176*	*150*	*166*	*134.5*	*161.5*
N1	14	14	14	14	14	14	14	14	14	14	14	14	14	14
N2	14	14	14	14	14	14	14	14	14	14	14	14	14	14
The statistic U =	102	80	189	175	149	121	124	121.5	155	125	151	135	166.5	139.5
mean U =	98	98	98	98	98	98	98	98	98	98	98	98	98	98
variance U =	474	474	474	474	474	473.7	473.67	473.7	473.7	473.7	473.7	473.7	473.7	473.7
std dev U =	22	22	21.8	21.8	21.8	21.76	21.764	21.76	21.76	21.76	21.76	21.76	21.76	21.76
z=	0.2	-0.9	4.16	3.51	2.32	1.057	1.1946	1.08	2.619	1.241	2.435	1.7	3.147	1.907
Are the 2 samples significantly different? i.e. is -1.96=< z=<1.96? For 95% confidence levels														
	No	No	**Yes**	**Yes**	**Yes**	No	No	No	**Yes**	No	**Yes**	No	**Yes**	No

Figure 9. 16 Mann-Whitney Analysis of Industrial Design Students vs. Known Innovators

9.5.2 Analysis of Industrial vs. Automotive Design Students

Figure 9. 18 presents the data table and results of a Mann-Whitney U test for two groups of data: L4 & L5 Industrial Design students and L4 & L5 Automotive Design students. Here an interesting pattern emerges. Given that we have seen from previous data tables and graphs a confused picture of the development of both groups, this test now brings a degree of clarity. What emerges from the analysis of the U test is how similar the data is at both Level 4 and Level 5. None of the traits demonstrates significant differences between the two groups. That is to say, the z statistic is not greater or equal to -1.96 or greater or equal to +1.96.

We can examine the results a little more closely to see if any trends emerge but these cannot be quantified with any statistical significance. From the first test at Level 4 we can see a distinct difference between the data. The Automotive Design group score higher than the ID group in all the traits. This is significant for potential recruitment to such programmes but does not necessarily affect our analysis. The aim of this research is to stimulate and nurture innovation so the important results are the so-called 'value-added' data. In each of the five innovation traits that comprise our Innovation Trait Index, the gap between Industrial Design and Automotive Design students narrowed and became negligible by the end of Level 5. The true test of whether or not this trend continues into Level 6 would be to follow both groups and test them once more at the end of their final year.

	Laterality				Forward Looking				Successful				Imaginative				Risk Taking				Confidence				Total			
	L4		L5		L4		L5		L4		L5		L4		L5		L4		L5		L4		L5		L4		L5	
		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk		Rk
ID001	34	8.5	37	10.5	33	18	34	17	35	17	29	3.5	30	15	31	16	33	13	35	16	32	9	31	4.5	163	15	160	10
ID002	27	1	34	7.5	30	11	29	6	34	15.5	36	17	30	15	32	17	32	9.5	34	13.5	37	17	39	16	163	15	170	13
ID003	36	13	30	1	24	2	30	8.5	34	15.5	35	13	27	9	28	11.5	23	1	29	5.5	28	3.5	30	3	136	4	152	6.5
ID004	34	8.5	44	22	33	18	27	2	28	4.5	21	1	29	12	29	14	37	17.5	33	10.5	33	10	28	1.5	160	11	138	1.5
ID005	38	17	41	17	31	12.5	34	17	36	18.5	35	13	34	21	34	21	30	7	31	8.5	41	22	42	22.5	172	20	176	18
ID006	28	2.5	31	2.5	27	7	28	3.5	25	2	28	2	24	3	24	2.5	24	2	27	2	25	2	31	4.5	125	1	138	1.5
ID007	38	17	42	19	23	1	25	1	21	1	32	7.5	28	11	25	5.5	32	9.5	34	13.5	22	1	28	1.5	126	2	144	3
ID008	46	22	42	19	34	21	38	22	33	13	33	9	36	23	33	19	39	21	40	20.5	37	17	40	18.5	179	22	184	23
ID009	36	13	33	5	26	5	33	15	27	3	35	13	30	15	29	14	33	13	41	22	37	17	41	20.5	153	7.5	179	19
ID010	32	7	33	5	31	12.5	34	17	29	7	39	22	25	4	27	9	33	13	40	20.5	29	5	33	8.5	147	6	173	16
ID011	38	17	42	19	27	7	29	6	28	4.5	35	13	26	6.5	27	9	26	4.5	28	3.5	28	3.5	33	8.5	135	3	152	6.5
ID012	36	13	38	12.5	29	9.5	32	13	38	21	39	22	30	15	33	19	37	17.5	37	17.5	36	14	39	16	170	19	180	21
ID013	41	20	39	14	25	3.5	32	13	30	9.5	31	5.5	26	6.5	25	5.5	26	4.5	30	7	30	6.5	32	6.5	137	5	150	4
ID014	31	5	38	12.5	36	22	39	23	33	13	37	20	34	21	33	19	34	15	37	17.5	36	14	38	13	173	21	184	23
Auto001	28	2.5	34	7.5	27	7	32	13	36	18.5	34	10	26	6.5	24	2.5	29	6	29	5.5	35	12	38	13	153	7.5	157	9
Auto002	31	5	35	9	33	18	35	19	30	9.5	37	20	22	1	27	9	38	19.5	33	10.5	38	20	41	20.5	161	13	173	16
Auto003	31	5	46	23	32	14.5	30	8.5	38	21	35	13	26	6.5	22	1	25	3	28	3.5	36	14	39	16	157	9	154	8
Auto004	35	10	40	15.5	25	3.5	31	10	29	7	36	17	33	19	36	23	36	16	34	13.5	38	20	36	11	161	13	173	16
Auto005	36	13	37	10.5	29	9.5	28	3.5	31	11	31	5.5	36	23	29	14	38	19.5	31	8.5	30	6.5	32	6.5	164	17	151	5
Auto006	37	15	31	2.5	33	18	36	20	38	21	45	23	32	18	28	11.5	32	9.5	26	1	35	12	38	13	170	19	173	16
Auto007	39	19	33	5	37	23	29	6	42	23	36	17	28	11	25	5.5	46	23	44	23	44	23	35	10	197	23	169	12
Auto008	42	21	40	15.5	32	14.5	32	13	33	13	32	7.5	23	2	25	5.5	32	9.5	34	13.5	38	20	42	22.5	158	10	165	11
Auto009	48	23	43	21	33	18	38	22	29	7	29	3.5	30	15	35	22	40	22	38	19	31	8	40	18.5	163	15	180	21

Figure 9. 17 Data set for Mann-Whitney Test

t-statistic (the Rank Sum for Auto students, the smaller group)	*113*	*110*	*126*	*114*	*131*	*116*	*101*	*94*	*128*	*98*	*135*	*131*	*125*	*112*
N1	9	9	9	9	9	9	9	9	9	9	9	9	9	9
N2	14	14	14	14	14	14	14	14	14	14	14	14	14	14
The statistic U =	58	61.5	45	58	40	55	70	77	43	73	37	40	46	59
mean U =	63	63	63	63	63	63	63	63	63	63	63	63	63	63
variance U =	252	252	252	252	252	252	252	252	252	252	252	252	252	252
std dev U =	16	15.9	15.9	16	15.9	16	16	15.9	15.9	15.9	16	15.87	16	16
z=	- 0.3	-0.1	- 1.13	- 0.3	-1.4	- 0.5	0.4	0.88	-1.3	0.63	- 1.7	- 1.449	- 1.1	- 0.3
	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Are the 2 samples significantly different? i.e. is -1.96=< z=<1.96? For 95% confidence levels

Figure 9. 18 Mann-Whitney Analysis of Industrial Design Students vs. Automotive Design Students

9.6 Review and Summary of Test Outcomes

Chapter 9 sets out the process by which the change in potential innovation propensity has been quantified. Raw data, in the form of the Innovation Trait Index, was collected, collated and analysed using a series of nonparametric tests. The purpose of the analysis was threefold: firstly, to quantify whether or not there was a significant change in potential innovation propensity; secondly, to determine the degree of similarity between Industrial Design students and both Known Innovators and Automotive Designers; and thirdly, to establish if there was any significant link between right/left hemisphere dominance and innovation propensity. The statistical analysis having been completed, the results are reported and conclusions drawn.

10 Conclusions

"Design is the whole experience of living."
(Karim Rashid, 2001)

This thesis has discussed an investigation into the nurture of innovation propensity in industrial design students through the creation of an environment and pedagogy conducive to the development of an innovative mindset. Furthermore, the investigation has aimed at establishing a mechanism for the measurement of innovation propensity by means of a novel Innovation Trait Index.

After developing an outline research methodology (chapter 1), the initial research was to effect an in-depth review of the innovation literature with respect to the theory of innovation practice at the individual and corporate level (chapter 2). This explored the nature of innovation and its nurture in terms of environment, mindset and culture. Preliminary observations were made relating to the study of innovation,

- There remains a lack of specific literature concerning the development of innovation within the creative industries.
- Much of the existing body of knowledge is concerned with the management and adoption of innovation in respect to goods and services.

Following on from this review a similar investigation was conducted of the established literature concerning industrial design (chapter 3). Particular attention was paid to its definition, its practice, the processes which govern it and its economic benefits. From this investigation, a number of issues emerged which provide an insight into the difficulties that are apparent when attempting to quantify the contribution of industrial design to the generation of intellectual property and the knowledge economy in general.

- Firstly, industrial design is a relatively new profession.
- Secondly, it straddles the two more traditional disciplines of engineering and art.

- Thirdly, it is difficult to identify the point at which the role of the industrial designer ends and that of the engineer or entrepreneur begins.

In parallel with the investigations described in chapters 2 and 3 a study was initiated of the innovation pedagogy within the industrial design programme at Swansea Institute (chapter 4). The investigation, Phase 0, considered the effect of pedagogy, programme structure and study environment on the development of innovation in industrial design. Two measurement tools were introduced based upon criteria identified in the literature. These were used to quantify the level of innovation demonstrated in each Major Project. Based upon the findings of the three investigations described in chapters 2, 3 and 4 a number of outcomes emerged:

- A new pedagogical approach was implemented
- A revised programme structure introduced
- The study environment was altered to facilitate innovation

The changes implemented as a direct consequence of the literature investigations and Phase 0 review were analysed in chapter 5. Phase 1 saw the introduction of a new modular teaching structure aimed at improving the opportunities for innovation in practice. The benefits of a new teaching and learning environment were assessed and reported on. Conclusions were developed which resulted in the formulation of a revision to the modular structure and new initiatives for the development of innovation within industrial design education. At the end of Phase 1 it was observed that:

- Communication and internal networking has improved
- Peer recognition in terms of student awards has improved
- The observed level of innovation had increased

The recommendations that emerged at the culmination of Phase 1 resulted in the implementation of a revised programme structure and an increase in the teaching of innovation theory within the programme. The implementation and evaluation of this new structure are discussed in chapter 6. In Phase 2, additional factors or indices were introduced to benchmark the level of innovation outputs. The Programme Management Team introduced a research strategy and an intellectual property rights scheme to stimulate innovativeness. The role of both schemes is discussed at length in the chapter concerned but it is valuable to note that both schemes had a direct impact on the students' perception of the value of their ideas. By providing an outlet for the expression of their novel ideas and concepts, the two schemes built up the students' self-confidence and encouraged risk taking. The positive outcomes identified from Phase 2 were identified as:

- Intellectual Property Rights scheme implemented
- Student research strategy developed
- Peer recognition in terms of student awards has improved
- Overall level of innovation has increased

Chapter 7 presented the implementation of a radical new module structure based upon a major review conducted at the end of Phase 2. The structural changes brought to an end the semesterisation of the programme. This allowed for longer and more flexible modules where students had the opportunity to experiment and innovate without fear of failing. The final Phase of the development of the programme, within the framework of this study, drew to a conclusion the analysis of the innovation outcomes. The data collected in the form of Likert data and a Likert-based model using evaluation criteria developed by Altshuller was analysed to determine its statistical relevance. The conclusions derived from Phase 3 are that:

- The level of innovation present in the major project has increased significantly with each phase. This has been observed by means of two Likert-based tests using a modified LBIO study and verified using a chi-squared test for statistical significance.

- The conclusion of Phase 3 brings to an end the observation of project outcomes and their associated statistical analysis. The phase saw the implementation of a new industrial design innovation pedagogy and the grading of project outcomes against two scales to determine level of innovation. Recommendations for the implementation of a five-point novel pedagogy for innovation in industrial design are forwarded (7.15).

Three key questions remained unanswered:

1. Can the effect of the programme of study on the individual's propensity to innovate be quantified?
2. What is the effect on the individual of studying under the industrial design innovation model presented here compared with students studying on a more traditional design programme?
3. To what extent does a graduate from the industrial design programme demonstrate a propensity for innovation compared to graduates from other programmes and known innovators?

Chapter 8 describes the development, implementation and analysis of a psychometric test devised with the aim of answering the three questions raised in 7.15. In order to answer the questions raised a testing methodology had to be developed. Thus far, the primary object of analysis had been the major project, now it was the mindset of the individual designer/innovator. Having determined to take the psychometric route the imperative was to investigate the literature and confirm the validity of using such an approach in this context. The test was then developed and piloted. The final test was benchmarked against a group of Known Innovators to determine the innovativeness norms. Each innovation trait was then compared against this norm before the Innovation Trait Index (ITI) confirmed. This tool was used to compare the propensity towards innovation of three groups against the Known Innovators. Statistical significance was determined using Spearman's Rank Correlation Test.
The analysis of graduates against Known Innovators was discussed and the conclusions recorded.

- Innovators are neither left nor right hemisphere [brain] dominated.
- Innovators have a balance between both hemispheres.
- Industrial and Automotive Design graduates have balanced brains but tend towards right dominance.

- Engineering graduates have balanced brains but with a strong left dominance.
- The median score for Industrial Design graduates is consistently higher in every trait than either Automotive Designers or Engineers but is lower than Known Innovators in two traits, Risk Taking and Self-Confidence.
- Industrial Design graduates produce the highest median statistic in the overall ITI score but not to any statistical significance.

It is clear from the data that industrial design graduates demonstrate a consistently higher propensity for innovation than those who have studied on comparable undergraduate programmes. The fact that this has not been statistically verified limits its application without further study but it does not invalidate the results shown.

Finally, the developed ITI was applied to Year 1 and Year 2 (Level 4 and Level5) undergraduates studying Industrial Design and Automotive Design (chapter 9). The aim was to answer the two remaining questions from 7.15,

- *What is the effect on the individual of studying under the industrial design innovation model presented here compared with students studying on a more traditional design programme?*
- *To what extent does a graduate from the industrial design programme demonstrate a propensity for innovation compared to graduates from other programmes and known innovators?*

A test methodology was developed with a view to answering both questions in unison. The data was first collated and then sorted to identify those individuals who had completed tests at both Level 4 and Level 5. The resulting data set was analysed using two nonparametric tests. The purpose of the analysis was twofold:

- To quantify whether or not there was a significant change in potential innovation propensity.
- To determine the degree of similarity between Industrial Design students and both Known Innovators and Automotive Designers

The Sign Test was conducted to determine the degree of similarity between the development of Industrial Designers and Automotive Designers. The implications of this test are that there appears to be a significant difference between the development of Industrial Design undergraduates and those studying Automotive Design.

The Mann-Whitney U Test was applied to identify the change in relationship between the Industrial Design students and Known Innovators. It is clear from the results for the overall ITI score that a change has occurred in the mindset of the ID students. The analysis demonstrates that by the end of Level 5 (year 2) they exhibit the necessary traits that would indicate their propensity to be innovators has increased. As the aim of this research is to stimulate and nurture innovation so the important results are the so-called 'value-added' data. In each of the five innovation traits that comprise the Innovation Trait Index, the gap between industrial design and automotive design students narrowed and became negligible by the end of Level 5. The true test of whether or not this trend continues into Level 6 would be to follow both groups and test them once more at the end of their final year.

It is concluded from the results of this qualitative and quantitative study that innovation can be nurtured given the right conditions and support. It can be measured and seen to increase over time as evidenced by the project outcomes. Additionally an individual's potential propensity towards innovation can be measured and the results used either as a selection tool or a diagnostic tool to identify aspect for development.

To sum up, the results of this investigation have shown that it is possible to affect significantly an individual's propensity towards innovation in industrial design through the creation of an appropriate innovation-led culture, environment and pedagogy. Furthermore, the study has revealed that an individual's propensity towards innovation is not dictated by nature but can be nurtured. This propensity can be measured at the project level but more significantly at the psychological level.

11 Future Work

"The best is yet to come."
(Jorge Pensi, 2001)

This thesis forms a foundation upon which to build future research. Having established an environment for the nurture and measurement of an innovation mindset amongst industrial design students, it would seem illogical to end the work of refinement and evolution of the model. Innovation has no beginning and no end. It is a constant process where change and the pursuit of the new are the only constants.

Initially future work will focus on the extension of the study to include an analysis of the Level 6 cohort set to graduate in June 2008. This would bring to a natural conclusion the work begun in 1997 by seeing Phase 3 through to its end review.

Following this, the scope of the work will be extended to embrace other fields within the creative industries such as Architectural Glass.

It is hoped that the work may embrace the wider socio-economic sphere by identifying ways in which the work may be used to fulfil part of the RSA's agenda for developing a capable population and encouraging enterprise.

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Appendices

Appendix 1 Phase 0 Project Data

Phase 0		Likert Scale		Altshuller Scale	
Student	Project	ID		ID	
0001	GPS Navigation & Communication Device	3		3	
0002	Compact Printer	3		3	
0003	Hypothermia Detector	3		2	
0004	Portable OHP	2		2	
0005	Disabled Minibus	1		2	
0006	Home Fitness Equipment	1		2	
0007	Hot Food Vacuum Flask	1		2	
0008	Wheel Changer	1		2	
0009	Rain Detector	2		2	
0010	Cycle Trailer for Africa	3		2	
0011	Clocks for the Visually Impaired	1		1	
0012	Surfer's Storage Unit	1		1	
0013	Modular Work Station Furniture	1		1	
0014	Push Chair	1		1	
0015	Electronic Drink Optic	1		1	
0016	Folding Trailer	1		1	
0017	Combined Floor Polisher & Vacuum Cleaner	1		1	
0018	Hands-free Hair Dryer	1		1	
0019	Advanced Motorcyclist's Boot	4		3	
0020	Paint Feeder System	4		2	
0021	Public Telephone Steriliser	2		2	
0022	Airport Multimedia Terminal	1		1	
0023	Disabled Walking Aid	1		1	
0024	Hard Shelled Back-pack	1		1	
0025	Commuter Vehicle	2		1	
0026	Garden Vacuum	1		1	
0027	Child Seat	1		1	
0028	Athlete's Pulse Monitor	2		1	
0029	Rape Alarm	2		1	
0030	Autoclave for Developing Countries	3		3	
0031	Hotel Door Security System	2		3	
0032	GRP Speaker System	1		2	
0034	Emergency Medical Shelter	2		2	
0035	Fireman's Helmet	1		2	
0036	Modular, Temporary Railway Station	3		2	
0037	Fitness & Rehabilitation Training Aid	1		1	
0038	Wheel Changer	2		1	
0039	MM Visor	4		1	
0040	Computer	2		1	
0041	Yacht Race Course Setting Equipment	2		1	

0042	Rambler's Communicator & Locator	2		**1**	
0043	Commuter's Bag & Bike Rack	1		**1**	
0044	Theatre Lighting Trainer	1		**1**	
0045	Shelving System	2		**1**	
0046	Child's Shower Seat	1		**1**	
0047	Hand Wrench	1		**1**	
0048	Saucepans for the Visually Impaired	1		**1**	
0049	Kitchen Can Crusher	2		**1**	
0050	Shopper's Bar Code Reader	2		**1**	
0051	Sports Car Roof Rack	2		**1**	
0052	Child's Learning Aid	1		**1**	
	Average	1.73		**1.47**	
	Number	51		51	

Appendix 2 Phase 1 Project Data

Phase 1		Likert Scale		Altshuller Scale	
Student	Project	ID		ID	
1001	Protective Packaging for Transplant Organs	3		3	
1002	CO & Smoke Alarm	2		3	
1003	Air Purifier	4		3	
1004	Scoptic Sensitivity Syndrome Diagnostic Device	3		3	
1005	Medical Computer for Paramedics	2		3	
1006	Multi-Water Sport Head Protector	3		3	
1007	Caving Helmet	3		3	
1008	Advanced Rail Transport System	1		2	
1009	Domestic Application of Alternative Technology	1		2	
1010	Disaster Rescue Management System	1		2	
1011	Home Entertainment System	1		2	
1012	Modular Table	1		2	
1013	Cordless Hairdryer	1		2	
1014	Vacuum Cleaner For Elderly & Disabled	1		2	
1015	Powered 'Golf Caddie'	1		2	
1016	Solar Powered Water Pasteurisation Equipment	3		2	
1017	Modular Commuter Back Pack	1		2	
1018	Food Warmer	1		2	
1019	Dedicated Police Vehicle	2		1	
1020	Odour Control System	1		1	
1021	Camper's Washing Machine	2		1	
1022	Seating Solutions for Home Office	1		1	
1023	Compact Vehicle for Commuting & Leisure	1		1	
1024	Water Filter for Disaster Situations	2		1	
1025	Domestic Oven & Hob	1		1	
1026	Coffee Machine	1		1	
1027	Child Seat	1		1	
1028	Electronic Police PDA	3		3	
1029	Digital Camera/Printer	4		3	
1030	Electronic Wearable Travel Companion	3		3	
1031	Avalanche Survival Suit	5		3	
1032	Home Entertainment Centre	2		3	
1033	Olfactory Response Simulator	4		3	
1034	Hydrofoil Jet-ski	3		2	
1035	Crash Helmet	1		2	

1036	Subterranean Parking System	2		2	
1037	Double Ended Surf Board	1		2	
1038	Portable A.I. Equipment	1		2	
1039	Shopping Trolley	1		2	
1040	Alternative Mobile Phone	2		2	
1041	Interactive First Aid	1		2	
1042	Info-fridge	2		2	
1043	Steerable Surf Board	3		2	
1044	Land Yacht	1		2	
1045	Remote Interactive Internet Interface	1		2	
1046	Restaurant Bar Coding Stock Control System	2		1	
1047	Recycling Education Centre	1		1	
1048	DIY Chainsaw Work Horse	1		1	
1049	Sink	1		1	
1050	Compact Fitness Centre	1		1	
1051	Interactive Recipe 'Book'	2		1	
1052	Electronic Musical Instrument	1		1	
1053	Snow Board	2		1	
1054	Innovative Home Heating Source	1		1	
1055	Language Tutor	1		1	
1056	Mpeg Music Player	2		1	
1057	Airport Trolley	1		1	
1058	Learner Driver Monitoring System	3		3	
1059	Demountable Leisure Vehicle	3		3	
1060	Diver's Propulsion Unit	3		3	
1061	Solar Cooker	1		2	
1062	Electronic Personal Swim Coach	3		2	
1063	Surf Rescue Craft	2		2	
1064	Home Security Verifier	2		2	
1065	Modular PC	3		2	
1066	Electric Foldaway Personal Transport	4		2	
1067	Enclosed Commuter Motorcycle	3		2	
1068	Fire Appliance for the New Millennium	1		2	
1069	Domestic Waste Separator	1		2	
1070	Rechargeable Tattoo Gun	2		2	
1071	Reef Viewing Vessel	2		2	
1072	Back Pain Relief Belt	1		1	
1073	Rechargeable Vacuum Cleaner	1		1	
1074	Bicycle Security Parking	1		1	
1075	GPS Tachograph	1		1	
1076	Bicycle Rack for Buses	1		1	
	Average	1.83		1.87	
	Number	76		76	

Appendix 3 Phase 2 Project Data

Phase 2		Likert Scale		Altshuller Scale	
Student	**Project**	**ID**	**Auto**	**ID**	**Auto**
2001	Development of a portable PC console	2		**1**	
2002	Exploration and development of a novel self-inflating life jacket	4		**3**	
2003	Development of adaptable furniture for the restaurant / bar environment	2		**2**	
2004	Development of the formal surfacing language of a future Concept Skoda		2		**1**
2005	Development of the formal surfacing language and application of brand values to a Concept Saloon		2		**1**
2006	Design and technical development of a dedicated professional rugby boot	3		**2**	
2007	Development and application of a novel ABS Brake system for bicycles	4		**2**	
2008	Development of the formal surfacing language of a new shopper's buggy	2		**1**	
2009	Exploration and development of a novel modular rescue vehicle for aerial deployment		5		**3**
2010	Development of the formal surfacing language of a future Audi truck		1		**1**
2011	Development and design of a novel ticketing system for the 2012 Olympics	3		**2**	
2012	Examination and development of a novel lamp post	3		**2**	
2013	Design of a Tri-pod canoe	2		**1**	
2014	Development of the formal surfacing language of a future Maserati		2		**2**
2015	Design and development of a novel Royal Mail bag	1		**1**	
2016	Biomorphic and Art Nouveau style to create a new language of vehicle form		2		**2**
2017	An exploration of the integration of communication and business technologies to create a new vehicle class		2		**2**
2018	An investigation into the issues associated with using a mobility aid	2		**1**	

2019	Changing the perceptions of vehicles with advanced fuel technologies		2		**2**
2020	2035 – Investigating the case for a new generation of Morgan sports cars		1		**1**
2021	An investigation into the specification and design of a dedicated police vehicle		3		**2**
2022	An investigation into the prevention of HCAI	3		**3**	
2023	Engaging children in developing a sustainable environment	3		**3**	
2024	Examining issues of perception and safety in the design of a narrow lane commuter vehicle		4		**3**
2025	First-time buyers – tackling the problems of buying an affordable yet safe and reliable new car		2		**1**
2026	Investigating the development of healthy lifestyles through design	2		**2**	
2027	Ford – the next generation. An investigation into the evolution of the Ford family for 2020		2		**2**
2028	Delivering an efficient portable pressure cleaning solution	3		**2**	
2029	3-wheel renaissance – exploring the application of low-emission technologies to re-invigorate the platform		2		**2**
2030	Supporting the needs of diabetics through better therapeutic design	1		**1**	
2031	An exploration of the use of glass in the design and manufacture of a musical instrument	4		**2**	
2032	2015 - Design and emotion in the 'urban jungle'. Can there be a safe 'green' car that is fun to drive?		3		**2**
2033	Re-inventing the camper van for the post-modern generation		1		**1**
2034	Cordless wall-mounted hifi system	1		**1**	
2035	Bridging the gap between Telecomm and Automotive Design – Nokia Automotive		2		**2**
2036	Soil monitoring system	3		**1**	
2037	Diminishing resources – Eco shelter	3		**3**	
2038	Wheelchair	2		**2**	

2039	Is there a need to help improve the game of golf? – Adjustable golf club	4		**2**	
2040	Reinterpreting the 750 race series		2		**1**
2041	Public information point	1		**1**	
2042	Electronic life coach	3		**2**	
2043	Personal expression within the motoring industry – IKEA		4		**2**
2044	The future of social entertainment outdoor jukebox	3		**3**	
2045	Expanding a brand into new markets. Billabong solar cooler	5		**4**	
2046	Alternative integrated public transport system		2		**2**
2047	Digital DJ mixing desk	3		**2**	
2048	I've fallen and I can't get up – mountain rescue stretcher	3		**2**	
2049	Automotive Freedom		2		**2**
2050	Retail information centre	3		**3**	
2051	Can a smaller fast-response vehicle ever replace the use of an ambulance in the UK?		2		**2**
2052	Personal alarm for men	4		**3**	
2053	Infant care environment	4		**3**	
2054	Can a vehicle improve the way of life in 3rd world countries?		4		**3**
2055	Avalanche rescue beacon system	2		**2**	
2056	Heated lumbar support	1		**1**	
2057	Integrated medical monitor	3		**3**	
2058	Lightweight sports car with unique integrated suspension		4		**3**
2059	PDA and study tool for the deaf	4		**3**	
2060	Wheelchair-accessible car		1		**1**
2061	Thermographic camera system	1		**1**	
2062	Emergency evacuation sled	2		**2**	
2063	Freezer bag	2		**2**	
2064	Kitchen safety and security monitor	3		**3**	
2065	Recycled street furniture	1		**2**	
2066	Electronic news media	4		**4**	
2067	Food processor	3		**2**	
2068	Fast food packaging collection point	3		**1**	
2069	Commuter coach		1		**1**
2070	Urban single-seat vehicle		3		**3**
2071	East European 4x4 concept		2		**1**
2072	Child's toy	3		**2**	
2073	Porche 2020 concept		3		**3**
2074	Recall – electronic information system	3		**2**	

2075	Police information point	3		3	
2076	Swanlink tram system		1		1
2077	Vehicle breakdown self-diagnostic system	3		2	
2078	Portable energy	2		1	
2079	Urban transportation	3		2	
2080	6X6 vehicle	1		1	
2081	Urban transportation	4		3	
2082	Wound treatment system	3		2	
2083	Water filtration	3		2	
2084	Truck security system	4		3	
2085	Soil turner	1		1	
2086	Action camera	1		1	
2087	Compact printer	4		3	
2088	Interaction furniture	1		1	
2089	Modular luggage	2		1	
2090	Cordless induction hob	4		2	
2091	Kite board	2		1	
2092	Oxygen converter	3		2	
2093	Interactive exercise system for kids	3		2	
2094	'Globe' – GPS personal locator	4		2	
2095	Surf board trailer	1		1	
2096	'Bubba Bear' – interactive child's learning toy	2		2	
2097	'La Tavolla' – ironing system	1		1	
2098	'Kineticar' – kinetic vehicle	2		1	
2099	'Little Extras' – child's safety harness	1		1	
2100	'Platform' – PC	4		1	
2101	'Wassh' – Mag-Lev washing machine	5		2	
2102	'ONE' – ice hockey helmet	2		2	
2103	'Nymo' – cylinder mower	5		3	
2104	Digital notice board	2		1	
2105	'Jaws' – organic waste system	1		1	
2106	Retail download drive	2		2	
2107	Lifeguard's pulse monitor	1		1	
2008	Rickshaw	1		1	
2009	'Chily' – portable fridge	2		1	
2010	'Ladeback' – games console chair	1		1	
2011	'L-SM' – light & sound machine	1		1	
2012	'Uniq' – domestic electric radiator	2		1	
2013	'Grub' – portable lunch heater	3		3	
2014	'Nani' – new child light	3		2	
2015	'Aurora' – personal heating solution	2		2	
2016	'POP - PODS' – interactive point of purchase kiosk	2		1	
2017	Shampoo dispenser	1		1	

	Average	2.52	2.30	**1.85**	**1.83**
	Number	**87**	**30**	**87**	**30**

Appendix 4 Phase 3 Project Data

Phase 3		Likert Scale		Altshuller Scale	
Student	Project	ID	Auto	ID	Auto
3001	An exploration of Bulgari brand values applied to the design of a luxury yacht		4		2
3002	Development of a novel adjustable child's car seat to comply with new legislation	4		3	
3003	Design of a dedicated hydraulic trolley for the safe handling of commercial removal boxes	2		3	
3004	Development of the formal surfacing language of a future Jaguar Concept		3		2
3005	Investigation of a novel combined sink/urinal as an aid to better personal hygiene and water saving	4		3	
3006	Development of a dedicated home work station	1		1	
3007	Development of the formal surfacing language of a future Concept Alpha Romeo		2		1
3008	Design of an electronic map unit for development of orienteering skills	3		2	
3009	Development of the formal surfacing language for an F1 derived Concept Alpha Romeo		3		2
3010	Development of a novel Concept Taxi for use in Paris 2050		4		3
3011	Design and development of electronic flexible screen book	4		2	
3012	Development of a novel water purification system utilising kinetic energy and LED technology	5		4	
3013	Design of a hands-free music training aid	3		2	
3014	Critical examination and novel design 15 proposal for the encouragement of healthy eating in children	5		3	
3015	Incremental improvement and redesign of an industrial powder dispensing valve	3		2	
3016	Development of a dedicated music download station and distribution strategy	2		2	

3017	Development of a water purification system for retail outlets and a novel marketing proposal	5		3	
3008	Design of a lightweight and ergonomic rescue helmet for use in crash recovery operations	4		2	
3009	Development of the formal surfacing language of a new generation Audi Quattro		2		1
3010	Design of a rotary clothes line for improved ergonomic access	2		1	
3011	Development of the formal surfacing language of a new generation Karmen Ghia		2		2
3012	Development of the formal surfacing language of a future BMW		2		2
3013	Personal fitness trainer involving embedded wearable technology	3		1	
	Average	3.33	2.75	**2.27**	**1.88**
	Number	15	8	15	8

Appendix 5 Psychometric Questionnaire

The following questionnaire has been produced as part of my PhD studies into the innovative mind. The questions need to be answered quickly - don't think about your response as your first answer is the one I need. There are no right or wrong answers to the questions - only honest ones. - Thanks - Ian Walsh

Firstly fill in your personal details (these will remain confidential) then systematically answer the questions. There are 155 questions but the entire questionnaire can be completed in 35 minutes.

Answer each question by typing the number **1** into the box corresponding to your answer

Example - In answer to the question 'Which of the following appeals to you most?' I chose answer 1b

P136/B2	1	Which of the following appeals to you most?			
P136/B2	1a	To be able to do things because I want to do them			
P136/B2	1b	to have a wonderful family life		1	
P136/B2	1c	to be highly successful in my chosen career			

Innovation Trait Index	CONFIDENTIAL
Name:	
Age [Years]:	
Sex [M/F]:	
Current Course:	
Qualification: **[Highest]**	

Laterality

P136/B2	1	Which of the following appeals to you most?			
P136/B2	1a	To be able to do things because I want to do them			
P136/B2	1b	to have a wonderful family life			
P136/B2	1c	to be highly successful in my chosen career			
P136/B2	2	How strongly do you rely on your intuition?			
P136/B2	2a	very strongly			
P136/B2	2b	not very strongly, although I have occasionally followed my gut feelings			
P136/B2	2c	hardly ever since I rely more on reason and logic			

P136/B2	3	Which of these best describes you?
P136/B2	3a	inquisitive
P136/B2	3b	well organised
P136/B2	3c	serious and studious
P136/B2	4	Which of the following most takes your breath away?
P136/B2	4a	one of nature's great wonders such as the Grand Canyon
P136/B2	4b	a great man-made structure such as the Taj Mahal
P136/B2	4c	a great operatic voice such as Pavarotti or Bryn Terfyl
P136/B2	5	How often do you worry about the way we treat our planet?
P136/B2	5a	very often
P136/B2	5b	occasionally
P136/B2	5c	hardly ever
P136/B2	6	Which of the following do you most admire?
P136/B2	6a	the flight of a bird
P136/B2	6b	the speed and grace of a cheetah
P136/B2	6c	the strength and courage of a lion
P136/B2	7	Do you like to set yourself targets and try to stick to them?
P136/B2	7a	no, I prefer to do things when I'm ready and in the right frame of mind
P136/B2	7b	I do sometimes forward plan but in a flexible sort of way
P136/B2	7c	yes, since that is the most efficient way to get things done
P136/B2	8	How important to you is punctuality?
P136/B2	8a	not important
P136/B2	8b	fairly important
P136/B2	8c	very important
P136/B2	9	Which of the following do you find most difficult when sitting examinations?
P136/B2	9a	concentrating and revising
P136/B2	9b	conquering my nerves beforehand
P136/B2	9c	worrying about whether I am going to score highly
P136/B2	10	Assuming you had time on your hands, which of the following would most appeal to you?
P136/B2	10a	taking up something creative like painting or sculpture
P136/B2	10b	taking up a sport such as golf or bowls
P136/B2	10c	joining a health club to keep myself in good shape

P136/B2	11	Which of these words best describes you?
P136/B2	11a	complex
P136/B2	11b	content
P136/B2	11c	calculating
P136/B2	12	How often do you have dreams that you are unable to explain?
P136/B2	12a	more than occasionally
P136/B2	12b	occasionally
P136/B2	12c	rarely or never
P136/B2	13	Which of these qualities best sums you up?
P136/B2	13a	unconventional
P136/B2	13b	wise
P136/B2	13c	patient
P136/B2	14	How often do you doodle?
P136/B2	14a	more than occasionally
P136/B2	14b	occasionally
P136/B2	14c	less than occasionally
P136/B2	15	Which of the following most irritates you?
P136/B2	15a	rules and regulations
P136/B2	15b	rudeness
P136/B2	15c	incompetence
P136/B2	16	How often do you get flashes of inspiration or new ideas to the extent that your mind cannot rest until you have tried to put them into practice?
P136/B2	16a	more than occasionally
P136/B2	16b	occasionally
P136/B2	16c	rarely or never
P136/B2	17	Do you find it difficult to complete a long task without breaking off to do other things?
P136/B2	17a	yes
P136/B2	17b	occasionally
P136/B2	17c	not usually
P136/B2	18	What worries you most about retirement?
P136/B2	18a	nothing worries me about retirement
P136/B2	18b	perhaps getting older and not being as fit as I was
P136/B2	18c	that I may get bored and have difficulty filling my time

P136/B2	19	Which of the following most closely represents your views on making mistakes?
P136/B2	19a	making mistakes is all part of life's experience and it is important we learn from them
P136/B2	19b	the only people who do not make mistakes are the people who do nothing and that is the greatest mistake of all
P136/B2	19c	we all make mistakes but in life the winners make less mistakes than life's losers
P136/B2	20	Which of these words best describes you?
P136/B2	20a	philosophical
P136/B2	20b	peaceful
P136/B2	20c	pragmatic
P136/B2	21	What are your views on the old adage *so much to do so little time to do it?*
P136/B2	21a	I agree and get quite frustrated about it at times
P136/B2	21b	I accept that there are many more things I would like to do if I ever get the opportunity but it is not something that worries or frustrates me
P136/B2	21c	it is not something that I give a great deal of thought to
P136/B2	22	Out of the following three choices which do you consider was your best subject at school?
P136/B2	22a	practical subjects such as art or design & technology
P136/B2	22b	sport
P136/B2	22c	mathematics
P136/B2	23	Do you believe that aggressive behaviour is sometimes necessary as a means to an end?
P136/B2	23a	not in any circumstances
P136/B2	23b	maybe in certain very rare circumstances
P136/B2	23c	yes
P136/B2	24	How would you best like to be described?
P136/B2	24a	imaginative and innovative
P136/B2	24b	amiable and well liked
P136/B2	24c	trustworthy and dependable
P136/B2	25	When making an important decision do you prefer to?
P136/B2	25a	make your own decision
P136/B2	25b	talk things over with someone and reach a joint decision
P136/B2	25c	seek advice from an expert

P136/B2	26	How organised are you when it comes to filing away important documents?
P136/B2	26a	not well organised at all
P136/B2	26b	reasonably well organised
P136/B2	26c	extremely well organised
P136/B2	27	Which of the following words do you believe is most applicable to yourself?
P136/B2	27a	visionary
P136/B2	27b	steady
P136/B2	27c	businesslike
P136/B2	28	Do you channel most of your energies into your chosen career?
P136/B2	28a	no
P136/B2	28b	I do take my career seriously but have time to enjoy a great deal of other things besides
P136/B2	28c	yes, I consider myself a specialist in my chosen career and it takes up a great deal of my time and energy
P136/B2	29	Which of the following best describes you?
P136/B2	29a	emotional
P136/B2	29b	decisive
P136/B2	29c	aggressive
P136/B2	30	Which of the following would most influence your choice of holiday destination?
P136/B2	30a	beautiful scenery
P136/B2	30b	sun, sea and sand
P136/B2	30c	exciting night life

Forward Looking

P54/B2	1	Do you like to keep abreast of the latest technology?
P54/B2	1a	not particularly
P54/B2	1b	to a certain extent
P54/B2	1c	yes

P54/B2	2	Do you constantly seek new hobbies and ventures?
P54/B2	2a	not really as any hobbies I have are things that I have been involved in, and have interested me, for many years
P54/B2	2b	not particularly, although the occasional new interest may present itself to me
P54/B2	2c	yes, I believe that every so often you just move on to new things
P54/B2	3	Do you go to new holiday places each year?
P54/B2	3a	no, I usually go to the same place each year
P54/B2	3b	not each year, since we have a few different favourite places that we like to alternate between
P54/B2	3c	usually
P54/B2	4	Which of these is the most important to you?
P54/B2	4a	the past
P54/B2	4b	the present
P54/B2	4c	the future
P54/B2	5	Do you tend to hoard things?
P54/B2	5a	yes
P54/B2	5b	perhaps
P54/B2	5c	no
P54/B2	6	Which of these most closely represents your thoughts on the 1st of January?
P54/B2	6a	here goes, another *annus horribilis*
P54/B2	6b	it doesn't seem anything like 12 months since last New Year
P54/B2	6c	what new projects have I got planned for this year
P54/B2	7	Do you believe there ever comes a time in life when you should just grow old gracefully?
P54/B2	7a	yes
P54/B2	7b	perhaps
P54/B2	7c	no
P54/B2	8	Is there a particular era in the past where they played *your kind of music*
P54/B2	8a	most certainly
P54/B2	8b	perhaps I do like music of a certain era better than today's stuff
P54/B2	8c	no

P54/B2	9	Do you own a PC?	
P54/B2	9a	no, and I have no plans to	☐
P54/B2	9b	no, but I hope to buy one in the future	☐
P54/B2	9c	yes	☐
P54/B2	10	Would fond memories of living happily in the same home for many years prevent you from moving on to pastures new if you had the opportunity?	
P54/B2	10a	yes	☐
P54/B2	10b	it would depend on what the pastures new were	☐
P54/B2	10c	no	☐
P54/B2	11	Which of the following is most important to you?	
P54/B2	11a	a content and stable family life	☐
P54/B2	11b	live life to the full	☐
P54/B2	11c	continually expand your mind to its full potential	☐
P54/B2	12	When you spend an evening with your nearest and dearest would you prefer to reminisce or plan for the future?	
P54/B2	12a	reminisce	☐
P54/B2	12b	both equally	☐
P54/B2	12c	plan for the future	☐
P54/B2	13	If someone does you a particularly bad turn do you ever forgive them entirely?	
P54/B2	13a	no	☐
P54/B2	13b	not until I've evened the score with them	☐
P54/B2	13c	forget them rather than forgive	☐
P54/B2	14	Do you have your own web page?	
P54/B2	14a	no	☐
P54/B2	14b	no, but I wouldn't rule out having one in the future	☐
P54/B2	14c	yes	☐
P54/B2	15	Have your idols/heroes remained the same through the years?	
P54/B2	15a	yes	☐
P54/B2	15b	yes although I have some modern idols/heroes too	☐
P54/B2	15c	no	☐

P54/B2	16	Does the thought of a new a seemingly complicated technology frighten you?
P54/B2	16a	yes
P54/B2	16b	more overwhelms and confuses me than frightens me
P54/B2	16c	not frightens me, but sometimes I cannot rest until I have got to grips with it
P54/B2	17	Which of these most closely represents your attitude to change?
P54/B2	17a	I hate change
P54/B2	17b	I don't particularly like change but accept its inevitability
P54/B2	17c	change does not worry me in the slightest
P54/B2	18	Do you prefer to watch repeats of vintage programmes on TV rather than new ones?
P54/B2	18a	yes
P54/B2	18b	sometimes
P54/B2	18c	no
P54/B2	19	What do you think about new fashions in clothing?
P54/B2	19a	not much
P54/B2	19b	some new fashions are OK I suppose
P54/B2	19c	much of it is not for me but I like seeing people in new fashions providing it suits them
P54/B2	20	How easily are you able to move on from personal tragedy?
P54/B2	20a	not at all easily, in fact it is a very long and difficult process
P54/B2	20b	I try to move on in time, although no one fully recovers from a serious personal tragedy of bereavement
P54/B2	20c	it is not easy. However, I do try to put it behind me and get on with the rest of my life as quickly as possible
P54/B2	21	Do you ever visit your old haunts to invoke happy memories and renew old acquaintances?
P54/B2	21a	more than occasionally
P54/B2	21b	occasionally
P54/B2	21c	never or rarely
P54/B2	22	Which of the following do you consider to be your greatest strength?
P54/B2	22a	organised
P54/B2	22b	responsible
P54/B2	22c	energetic

P54/B2	23	How do you feel about the company you work for constantly introducing the latest technology?	
P54/B2	23a	somewhat apprehensive, since I feel more comfortable with what I know	☐
P54/B2	23b	I realise it is necessary in today's world in order to remain competitive, but I sometimes worry I will not be able to adapt to the new technology	☐
P54/B2	23c	I welcome it as an exciting new challenge	☐
P54/B2	24	Do you think your school days were the happiest of your life?	
P54/B2	24a	yes	☐
P54/B2	24b	not particularly, although I do have fond memories of my school days	☐
P54/B2	24c	no	☐
P54/B2	25	Have you ever mastered an item of new technology to the extent that you have shown someone else how to use it?	
P54/B2	25a	no	☐
P54/B2	25b	occasionally	☐
P54/B2	25c	more than occasionally	☐

Likely to be a Success

P42/B1	1	Do you find it easy to concentrate on one subject?	
P42/B1	1a	not at all, I like to diversify my interests	☐
P42/B1	1b	I try hard but it's difficult at times	☐
P42/B1	1c	yes. I have no problem doing this	☐
P42/B1	2	Do you ever find that your hobby interferes with your day job?	
P42/B1	2a	yes, often	☐
P42/B1	2b	sometimes	☐
P42/B1	2c	never	☐
P42/B1	3	You are looking forward to a weekend at home with the family when suddenly an urgent job crops up on a Friday afternoon, What is your reaction?	
P42/B1	3a	you say it will have to wait as you have already made plans for the weekend	☐
P42/B1	3b	you try to get someone else to do the job for you	☐
P42/B1	3c	you forfeit the weekend to get the job done	☐

P42/B1	4	You move to a new job and the local college is advertising a course which is very relevant to the job you are doing. How would you react?
P42/B1	4a	not really interested in going on the course
P42/B1	4b	only go on the course if it was paid for by the company
P42/B1	4c	be very interested in going on the course even if you had to pay for it yourself
P42/B1	5	You are feeling particularly unwell one morning and wonder if you are coming down with a heavy cold or even the flu. How would you behave?
P42/B1	5a	certify yourself sick and hope that you can shake it off by having a day at home
P42/B1	5b	go to the surgery and ask for the doctor's opinion on whether you are fit for work
P42/B1	5c	go to work and struggle on for as long as you can
P42/B1	6	How often do you grumble about the company you work for to friends and family?
P42/B1	6a	often
P42/B1	6b	sometimes
P42/B1	6c	very rarely
P42/B1	7	Where do you see yourself in five years' time?
P42/B1	7a	probably doing the same job
P42/B1	7b	hopefully in some better position
P42/B1	7c	I fully intend having advanced my career considerably in the next five years
P42/B1	8	You are asked to go on a residential training course which happens to be just five miles from your home address. What do you say?
P42/B1	8a	I will go on the course but as it's so near where I live I will not stay overnight
P42/B1	8b	I will go on the course but will only stay overnight if the company prefer me to
P42/B1	8c	I will stay overnight because I am part of a team and don't want to be the odd one out
P42/B1	9	Do you feel grumpy in the morning?
P42/B1	9a	only when it's a working day
P42/B1	9b	I do sometimes
P42/B1	9c	very rarely, I regard every day as an exciting new challenge
P42/B1	10	Do you talk about your job outside work?
P42/B1	10a	no, I turn off as quickly as I can at the end of each working day
P42/B1	10b	I do sometimes
P42/B1	10c	very frequently

P42/B1	11	Are you doing the job you always knew you wanted to do?
P42/B1	11a	not at all
P42/B1	11b	I perhaps thought I might do something along these lines
P42/B1	11c	yes, it's what I always planned to do
P42/B1	12	Do you think intelligence leads to success?
P42/B1	12a	yes, you must be intelligent to make a success in life
P42/B1	12b	it is a big contributory factor
P42/B1	12c	intelligence alone doesn't lead to success
P42/B1	13	Do you think you should have six-monthly assessment meetings with your boss?
P42/B1	13a	certainly not, what a waste of time
P42/B1	13b	yes, although I would be apprehensive before such a meeting
P42/B1	13c	yes, they are an excellent idea and a great opportunity to discuss aspects of my job and career in detail
P42/B1	14	Do you consider yourself ruthless?
P42/B1	14a	no, I don't like people who are ruthless
P42/B1	14b	maybe a little
P42/B1	14c	I'm afraid I am when it comes to getting what I want
P42/B1	15	How do you feel about going for interviews
P42/B1	15a	terrified
P42/B1	15b	perhaps somewhat nervous
P42/B1	15c	I enjoy interviews, and the opportunity to show people what I'm made of
P42/B1	16	One of your colleagues gets promoted. How do you feel?
P42/B1	16a	pleased for your colleagues
P42/B1	16b	a little envious
P42/B1	16c	quite upset and wanting to find out why it wasn't me and what went wrong
P42/B1	17	What do you think about hard work?
P42/B1	17a	it is very tiring
P42/B1	17b	it's OK as long as you get paid for it
P42/B1	17c	it is a means to an end
P42/B1	18	If you won the lottery jackpot what would you do?
P42/B1	18a	retire and live a life of luxury
P42/B1	18b	invest in a business and pay someone to run it
P42/B1	18c	carry on working on some sort of enterprise

P42/B1	19	Do you like sitting on committees?
P42/B1	19a	not really
P42/B1	19b	if pressed I have sat on them occasionally
P42/B1	19c	I prefer to be on the committee of any organisation of which I am a member
P42/B1	20	To what use would you prefer to put a particular talent?
P42/B1	20a	it would make a nice hobby
P42/B1	20b	it's something there to use when the need arises
P42/B1	20c	I would try to build a career around it if possible
P42/B1	21	Do you believe that practice makes perfect?
P42/B1	21a	no one is perfect
P42/B1	21b	people don't have much time to practise at things in this day and age
P42/B1	21c	yes, the harder you work at something the better you become
P42/B1	22	Do you believe in the power of hindsight?
P42/B1	22a	no, you cannot alter what has gone
P42/B1	22b	sometimes, I suppose, but anyone can be wise with hindsight
P42/B1	22c	it's important to look back and analyse our mistakes to ensure we don't repeat them in the future
P42/B1	23	Is it important to impress the right people?
P42/B1	23a	no, that's crawling
P42/B1	23b	sometimes
P42/B1	23c	yes
P42/B1	24	Which of these historical characters would you most like to shake the hand of and congratulate?
P42/B1	24a	Casanova
P42/B1	24b	Jesse James
P42/B1	24c	Robert the Bruce
P42/B1	25	From where do you get your motivation?
P42/B1	25a	from my boss
P42/B1	25b	from my immediate family
P42/B1	25c	from within

Imagination

P136/B1	1	Which of the following is your favourite type of book?
P136/B1	1a	who dunnit
P136/B1	1b	encyclopedia
P136/B1	1c	autobiography
P136/B1	2	At which of the following would you prefer to spend a week's holiday?
P136/B1	2a	a theme park such as Alton Towers
P136/B1	2b	an apartment in London
P136/B1	2c	a cottage by the sea
P136/B1	3	How often do you doodle?
P136/B1	3a	quite often
P136/B1	3b	sometimes
P136/B1	3c	rarely
P136/B1	4	Which of these is your idea of a perfect garden?
P136/B1	4a	one of natural beauty, wild flowers, a stream running through it and a wood
P136/B1	4b	neat and orderly with lots of formal flower beds and features
P136/B1	4c	a place primarily for relaxation with large lawn and hedges for privacy
P136/B1	5	You wish to hold a celebration bash for all your friends and family because you have won several million pounds on the lottery. Which of the following would be most ideal for this celebration?
P136/B1	5a	take them to Euro Disney for two days
P136/B1	5b	hire the local town hall and throw the world's greatest ever party
P136/B1	5c	take over a high class hotel and let them all live a weekend of luxury
P136/B1	6	Do you like repairing things?
P136/B1	6a	yes
P136/B1	6b	only if I know what is wrong and I know how to carry out the repair successfully
P136/B1	6c	no
P136/B1	7	If you could start your career over again and were guaranteed success in a chosen profession which of the following would you like to be?
P136/B1	7a	brain surgeon
P136/B1	7b	barrister
P136/B1	7c	politician

P136/B1	8	Which of these would you prefer to cultivate as a hobby?
P136/B1	8a	something artistic such as pottery
P136/B1	8b	some form of sporting activity
P136/B1	8c	collecting things such as antiques
P136/B1	9	Do you like messing around on computers?
P136/B1	9a	yes
P136/B1	9b	perhaps if I had more time
P136/B1	9c	no
P136/B1	10	If you cannot get to sleep at night which of the following is most likely to be the reason?
P136/B1	10a	mind is too over active
P136/B1	10b	I'm worried about something
P136/B1	10c	I'm not tired
P136/B1	11	If you have a really heavy workload and tight deadlines which of the following options would most apply to you in this situation?
P136/B1	11a	plan ahead and decide the most efficient way of dealing with the workload
P136/B1	11b	prioritise the workload and do the most urgent jobs first
P136/B1	11c	get your head down and get the work completed by sheer hard graft
P136/B1	12	Which of these would you prefer to give your partner as a gift at Christmas?
P136/B1	12a	a surprise gift of something you knew they had always wanted
P136/B1	12b	something which you've gone out on a shopping trip and chosen together
P136/B1	12c	shopping vouchers for a large department store to enable them to choose their own gift
P136/B1	13	If you went to an old time music hall which of the following speciality acts would you prefer to see?
P136/B1	13a	conjurer
P136/B1	13b	juggler
P136/B1	13c	acrobat

P136/B1	14	Which of the following dogs would you prefer as a pet?
P136/B1	14a	a little scamp of a dog always up to mischief
P136/B1	14b	a well behaved and well groomed and affectionate dog
P136/B1	14c	a totally devoted dog who you know would defend you and your property to the last
P136/B1	15	Which of these sports interest you the most?
P136/B1	15a	golf
P136/B1	15b	soccer
P136/B1	15c	boxing
P136/B1	16	If you had the opportunity to watch one of the following Hitchcock movies which one would you chose?
P136/B1	16a	Psycho
P136/B1	16b	The Birds
P136/B1	16c	Rear Window
P136/B1	17	Which of these words would you say most apply to yourself?
P136/B1	17a	whimsical
P136/B1	17b	dynamic
P136/B1	17c	ordinary
P136/B1	18	Which of the following TV shows would you have most like to have written?
P136/B1	18a	Fawlty Towers
P136/B1	18b	Dad's Army
P136/B1	18c	Rising Damp
P136/B1	19	Which of these puzzles do you enjoy solving the most in newspapers and magazines?
P136/B1	19a	crossword puzzles
P136/B1	19b	anagrams
P136/B1	19c	word searches
P136/B1	20	Do you believe in the paranormal?
P136/B1	20a	I would have to say that I do
P136/B1	20b	I am open minded on the subject
P136/B1	20c	no

P136/B1	21	Which of the following most accurately reflects your views on modern art?	
P136/B1	21a	it is creative and challenges the mind	☐
P136/B1	21b	occasionally I have seen a piece of modern art that interests me	☐
P136/B1	21c	to be perfectly frank I don't like it one little bit	☐
P136/B1	22	Do you ever feel frustrated that you should be doing something more interesting in life?	
P136/B1	22a	yes, frequently	☐
P136/B1	22b	sometimes	☐
P136/B1	22c	just occasionally	☐
P136/B1	23	Which of the following would be your dream home?	
P136/B1	23a	a 19th century mansion house with lots of rooms and corridors and steeped in history	☐
P136/B1	23b	a spacious farmhouse on the edge of the moors with acres of land	☐
P136/B1	23c	a modern five-bedroomed detached house with all mod cons in its own grounds	☐
P136/B1	24	Which of the following words best describes you?	
P136/B1	24a	curious	☐
P136/B1	24b	industrious	☐
P136/B1	24c	fulfilled	☐
P136/B1	25	Would you describe yourself as a follower of fashion?	
P136/B1	25a	not really I prefer my own thing	☐
P136/B1	25b	to a certain extent	☐
P136/B1	25c	yes generally	☐

Risk Taker

P49/B1	1	What are your views on the old adage, 'You must speculate to accumulate'?	
P49/B1	1a	don't agree	☐
P49/B1	1b	it is sometimes true	☐
P49/B1	1c	agree	☐
P49/B1	2	How often do you drive through a red light?	
P49/B1	2a	never	☐
P49/B1	2b	occasionally	☐
P49/B1	2c	more than occasionally	☐

P49/B1	3	Have you ever taken part in a dangerous sport?
P49/B1	3a	no
P49/B1	3b	no, but I wouldn't rule it out the possibility
P49/B1	3c	yes
P49/B1	4	Are you afraid of flying?
P49/B1	4a	yes
P49/B1	4b	a little
P49/B1	4c	not at all
P49/B1	5	Would you ever make a parachute jump?
P49/B1	5a	no way
P49/B1	5b	maybe
P49/B1	5c	yes
P49/B1	6	You are taking part in the quiz show 'Who Wants to be a Millionaire?'. You have just won £64,000. The next question is worth £125,000 if you answer correctly, but if you are wrong you drop back to £32,000. You have narrowed the answer down to two possibilities and are 75% sure of the answer. Would you gamble or walk away with £64,000?
P49/B1	6a	take the money
P49/B1	6b	don't know it would depend on how I felt at the time
P49/B1	6c	gamble
P49/B1	7	You have been in a steady job for 15 years which provides a decent lifestyle and security for you and your family. One day you are headhunted by a company which offers you 25% more salary but less security. Would you take the new job?
P49/B1	7a	very doubtful
P49/B1	7b	I would consider it very carefully
P49/B1	7c	I probably would
P49/B1	8	How often have you exceeded the 70 miles per hour speed limit on the motorway?
P49/B1	8a	never
P49/B1	8b	occasionally
P49/B1	8c	more than occasionally
P49/B1	9	Do you believe in taking calculated risks?
P49/B1	9a	no
P49/B1	9b	occasionally
P49/B1	9c	yes

P49/B1	10	Which of the following most accurately represents your views on insurance?
P49/B1	10a	I believe in over-insurance rather than under-insurance
P49/B1	10b	I insure where necessary and where it is prudent to do so
P49/B1	10c	insurance is a necessary evil
P49/B1	11	Have you ever done something daring and risky that you hoped no one would find out about?
P49/B1	11a	not that I can recall
P49/B1	11b	I suppose I have occasionally
P49/B1	11c	yes, in fact it gave me something of a kick
P49/B1	12	Would you ever climb on the roof of your house to repair tiles?
P49/B1	12a	no way
P49/B1	12b	I might, but would be quite apprehensive
P49/B1	12c	it would not worry me in the slightest
P49/B1	13	You have booked a holiday in London and two days before you are to go, two terrorist bombs are exploded. Would you still take the holiday?
P49/B1	13a	no, I would probably cancel
P49/B1	13b	London is a big place and the chances of being injured are very slight even if another bomb exploded, therefore I would probably still go
P49/B1	13c	I would not dream of cancelling
P49/B1	14	If you were out of work long term and got the offer of a job that involved danger, such as in the police force or fire brigade, would you take the job?
P49/B1	14a	no
P49/B1	14b	possibly
P49/B1	14c	yes
P49/B1	15	When you are a pedestrian do you ever cross a road when the lights are at red if you can see that the road is clear?
P49/B1	15a	no
P49/B1	15b	sometimes
P49/B1	15c	always
P49/B1	16	You have won £50,000 on the Premium Bonds and wish to invest £25,000 of it. Which of the following would you be more likely to choose?
P49/B1	16a	plough it back into Premium Bonds
P49/B1	16b	highest interest building society account

P49/B1	16c	very high interest investment account with a small degree of risk	☐
P49/B1	17	A night out at which one of the following most appeals to you?	
P49/B1	17a	bingo hall	☐
P49/B1	17b	greyhound racing	☐
P49/B1	17c	casino	☐
P49/B1	18	Would you ever stake a week's wage on one turn of a card?	
P49/B1	18a	no way	☐
P49/B1	18b	I would have to have plenty of Dutch courage first	☐
P49/B1	18c	yes, how exciting	☐
P49/B1	19	Would you ever leave a very steady, secure but mundane job to do something much less secure but that you really enjoyed?	
P49/B1	19a	no	☐
P49/B1	19b	maybe	☐
P49/B1	19c	yes	☐
P49/B1	20	In which of the following US cities would you prefer to live?	
P49/B1	20a	Boston	☐
P49/B1	20b	Dallas	☐
P49/B1	20c	New York	☐
P49/B1	21	When you first book into a hotel room, do you read the fire regulations?	
P49/B1	21a	yes	☐
P49/B1	21b	sometimes, if I notice them	☐
P49/B1	21c	no	☐

P49/B1	22	Would you ever break the law if you had the opportunity, it was considerably to your advantage to do so, and it was almost certain you would get away with it?	
P49/B1	22a	no, I wouldn't dare even if I wanted to	☐
P49/B1	22b	I doubt it, but no one can be absolutely certain unless faced with the circumstances.	☐
P49/B1	22c	I suspect I would	☐
P49/B1	23	How often have you been on a really terrifying ride at a fun-fair?	
P49/B1	23a	never or only once	☐
P49/B1	23b	more than once but only because I was with friends	☐
P49/B1	23c	more than once because I really enjoy the thrill and the excitement	☐

P49/B1	24	Would you ever take liberties with your health, such as smoke cigarettes?
P49/B1	24a	no
P49/B1	24b	I have done in the past, but have learnt it isn't a wise thing to do
P49/B1	24c	yes, if you call smoking taking liberties with your health
P49/B1	25	To be described as which of the following would secretly please you?
P49/B1	25a	steady and faithful
P49/B1	25b	wise and dependable
P49/B1	25c	wild and outrageous

Confidence

P228/B2	1	Would you take part in a TV quiz show?
P228/B2	1a	Yes
P228/B2	1b	Don't Know
P228/B2	1c	No
P228/B2	2	Would you be confident about being best man at a wedding?
P228/B2	2a	Yes
P228/B2	2b	Don't Know
P228/B2	2c	No
P228/B2	3	Are you a very positive person?
P228/B2	3a	Yes
P228/B2	3b	Don't Know
P228/B2	3c	No
P228/B2	4	Would you like to fly a plane?
P228/B2	4a	Yes
P228/B2	4b	Don't Know
P228/B2	4c	No
P228/B2	5	Would you like to meet Royalty?
P228/B2	5a	Yes
P228/B2	5b	Don't Know
P228/B2	5c	No

P228/B2	6	Have you ever argued with a superior?
P228/B2	6a	Yes
P228/B2	6b	Don't Know
P228/B2	6c	No
P228/B2	7	Would you care if friends saw you naked?
P228/B2	7a	Yes
P228/B2	7b	Don't Know
P228/B2	7c	No
P228/B2	8	Would you argue with a Traffic Warden if you thought you were right?
P228/B2	8a	Yes
P228/B2	8b	Don't Know
P228/B2	8c	No
P228/B2	9	Do you believe that 'attack is the best form of defence'?
P228/B2	9a	Yes
P228/B2	9b	Don't Know
P228/B2	9c	No
P228/B2	10	Are you confident driving in heavy traffic?
P228/B2	10a	Yes
P228/B2	10b	Don't Know
P228/B2	10c	No
P228/B2	11	Are you confident when crossing roads?
P228/B2	11a	Yes
P228/B2	11b	Don't Know
P228/B2	11c	No
P228/B2	12	Would you go on ferries in rough weather?
P228/B2	12a	Yes
P228/B2	12b	Don't Know
P228/B2	12c	No
P228/B2	13	Are you sometimes inclined to be ruthless?
P228/B2	13a	Yes
P228/B2	13b	Don't Know
P228/B2	13c	No

P228/B2	14	Are you unafraid of persons in authority?
P228/B2	14a	Yes
P228/B2	14b	Don't Know
P228/B2	14c	No
P228/B2	15	Do you ignore warning signs?
P228/B2	15a	Yes
P228/B2	15b	Don't Know
P228/B2	15c	No
P228/B2	16	Would you take a more difficult occupation?
P228/B2	16a	Yes
P228/B2	16b	Don't Know
P228/B2	16c	No
P228/B2	17	Would you like to appear live on a television talk show?
P228/B2	17a	Yes
P228/B2	17b	Don't Know
P228/B2	17c	No
P228/B2	18	Do you think you are cleverer than average?
P228/B2	18a	Yes
P228/B2	18b	Don't Know
P228/B2	18c	No
P228/B2	19	Would you direct a play on stage?
P228/B2	19a	Yes
P228/B2	19b	Don't Know
P228/B2	19c	No
P228/B2	20	Would you be confident to drive in a car rally?
P228/B2	20a	Yes
P228/B2	20b	Don't Know
P228/B2	20c	No
P228/B2	21	Would you walk through a cemetery at night?
P228/B2	21a	Yes
P228/B2	21b	Don't Know
P228/B2	21c	No

P228/B2	22	Would you fly in a micro-light aircraft?
P228/B2	22a	Yes
P228/B2	22b	Don't Know
P228/B2	22c	No
P228/B2	23	Would you like to be a politician?
P228/B2	23a	Yes
P228/B2	23b	Don't Know
P228/B2	23c	No
P228/B2	24	Would you walk on a tight rope?
P228/B2	24a	Yes
P228/B2	24b	Don't Know
P228/B2	24c	No
P228/B2	25	Would you tackle a burglar?
P228/B2	25a	Yes
P228/B2	25b	Don't Know
P228/B2	25c	No

The questions are taken from:
Carter, P. & Russell, K. (2001), Psychometric Testing –
1000 Ways to Assess Your Personality, Creativity, Intelligence and Lateral Thinking, Wiley,
Carter, P. & Russell, K. (2003), More Psychometric Testing –
1000 New Ways to Assess Your Personality, Creativity, Intelligence and Lateral Thinking, Wiley,
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Appendix 6 Raw Data for Level 4 Industrial Design Undergraduates

Industrial Design L4		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Laterality	34	32	44	43	45	41	39	37	28	46	40	36	36	34	37	35	40
	Forward Looking	33	33	36	37	34	31	33	36	27	34	24	21	37	29	36	32	35
	Successful	28	38	31	36	36	32	34	29	25	33	23	29	29	27	32	30	34
	Imaginative	29	30	31	37	30	29	27	26	24	36	30	23	21	32	35	32	31
	Risk Taking	37	25	38	43	35	39	32	32	24	39	31	27	36	37	36	43	38
	Confidence	33	35	35	42	38	39	35	33	25	37	30	26	27	37	40	33	36
	Total	160	161	171	195	173	170	161	156	125	179	138	126	150	162	179	170	174
	Median	33.0	33.0	35.0	37.0	35.0	32.0	33.0	32.0	25.0	36.0	30.0	26.0	29.0	32.0	36.0	32.0	35.0
	Standard Deviation	3.61	4.97	3.11	3.24	2.97	4.69	3.11	3.83	1.22	2.39	3.78	3.19	6.63	4.56	2.86	5.15	2.59

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Median	Std D
34	36	31	30	35	38	26	27	39	30	40	32	38	36	41	38	36	36.00	4.95
33	24	36	36	30	31	36	30	40	33	24	31	23	26	25	27	29	32.50	4.83
35	34	33	33	28	36	28	34	42	30	27	29	21	27	30	28	38	30.50	4.48
30	27	34	30	32	34	23	30	28	26	29	25	28	30	26	26	30	30.00	3.75
33	23	34	33	32	30	24	32	45	26	29	33	32	33	26	26	37	33.00	5.72
32	28	36	38	28	41	36	37	37	31	26	29	22	37	30	28	36	35.00	5.04
163	136	173	170	150	172	147	163	192	146	135	147	126	153	137	135	170	161.00	18.43
33.0	27.0	34.0	33.0	30.0	34.0	28.0	32.0	40.0	30.0	27.0	29.0	23.0	30.0	26.0	27.0	36.0		
1.82	4.32	1.34	3.08	2.00	4.39	6.31	2.97	6.50	3.11	2.12	2.97	4.66	4.51	2.41	1.00	4.18		

Appendix 7 Raw Data for Level 5 Industrial Design Undergraduates

Industrial Design L5		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Median	Std D
	Laterality	37	38	34	42	42	33	30	33	31	38	45	42	41	43	44	39	38.50	4.81
	Forward Looking	34	39	29	25	29	33	30	34	28	32	32	38	35	35	27	32	32.00	3.86
	Successful	29	37	36	32	35	35	35	39	28	39	22	33	30	32	21	31	32.50	5.28
	Imaginative	31	33	32	25	27	29	28	27	24	33	28	33	31	34	29	25	29.00	3.22
	Risk Taking	35	37	34	34	28	41	29	40	27	37	40	40	38	23	33	30	34.50	5.41
	Confidence	31	38	39	28	33	41	30	33	31	39	39	40	35	27	28	32	33.00	4.75
	Total	160	184	170	144	152	179	152	173	138	180	161	184	169	151	138	150	160.50	15.83
	Median	31.0	37.0	34.0	28.0	29.0	35.0	30.0	34.0	28.0	37.0	32.0	38.0	35.0	32.0	28.0	31.0		
	Standard Deviation	2.45	2.28	3.81	4.09	3.44	5.22	2.70	5.22	2.51	3.32	7.56	3.56	3.27	5.07	4.34	2.92		

Appendix 8 Raw Data for Level 4 Automotive Design Undergraduates

Automotive Design L4	1	2	3	4	5	6	7	8	9	10
Laterality	36	31	32	33	35	41	38	37	36	31
Forward Looking	29	33	28	35	25	35	35	33	24	32
Successful	31	30	36	39	29	35	32	38	33	38
Imaginative	36	22	23	32	33	31	24	32	25	26
Risk Taking	38	38	30	29	36	36	36	32	38	25
Confidence	30	38	33	35	38	41	38	35	35	36
Total	164	161	150	170	161	178	165	170	155	157
Average	32.8	32.2	30.0	34.0	32.2	35.6	33.0	34.0	31.0	31.4
Standard Deviation	3.96	6.65	4.95	3.74	5.26	3.58	5.48	2.55	6.20	5.81

11	12	13	14	15	16	17	18	19	20	21	22	23	Median	Std D
33	31	34	39	39	42	28	48	39	39	41	30	35	36.00	4.70
29	32	29	37	29	32	27	33	31	29	27	36	39	32.00	3.89
39	31	31	42	30	33	36	29	25	31	38	33	38	33.00	4.22
37	29	24	28	31	23	26	30	32	30	31	26	28	29.00	4.17
31	39	34	46	31	32	29	40	38	39	37	18	31	36.00	5.85
29	38	32	44	38	38	35	31	39	35	40	35	39	36.00	3.61
165	169	150	197	159	158	153	163	165	164	173	148	175	164.00	10.80
33.0	33.8	30.0	39.4	31.8	31.6	30.6	32.6	33.0	32.8	34.6	29.6	35.0		
4.69	4.44	3.81	7.20	3.56	5.41	4.62	4.39	5.70	4.15	5.41	7.57	5.15		

Appendix 9 Raw Data for Level 5 Automotive Design Undergraduates

Automotive Design L5	1	2	3	4	5	6	7	8	9	10
Laterality	34	46	35	36	41	43	37	43	32	31
Forward Looking	32	32	35	27	34	38	28	33	31	33
Successful	34	33	33	37	35	29	31	16	35	35
Imaginative	24	29	32	33	34	35	29	30	23	28
Risk Taking	29	37	34	33	31	38	31	35	30	35
Confidence	38	38	40	34	42	40	32	27	29	42
Total	157	169	174	164	176	180	151	141	148	173
Average	31.4	33.8	34.8	32.8	35.2	36.0	30.2	28.2	29.6	34.6
Standard Deviation	5.27	3.70	3.11	3.63	4.09	4.30	1.64	7.46	4.34	5.03

11	12	13	14	15	16	17	18	19	20	21	22	23	Median	Std D
40	46	40	35	37	33	31	44	32	31	33	40	41	37.00	4.98
28	30	31	35	28	29	34	35	27	36	30	32	36	32.00	3.18
30	35	36	37	33	36	41	37	30	45	34	32	38	35.00	5.32
31	22	36	27	28	25	30	27	29	28	21	25	33	29.00	4.11
40	28	34	33	24	44	33	37	36	26	21	34	33	33.00	5.13
38	39	36	41	29	35	26	37	36	38	26	42	31	37.00	5.26
167	154	173	173	142	169	164	173	158	173	132	165	171	167.00	12.85
33.4	30.8	34.6	34.6	28.4	33.8	32.8	34.6	31.6	34.6	26.4	33.0	34.2		
5.27	6.53	2.19	5.18	3.21	7.26	5.54	4.34	4.16	7.73	5.68	6.08	2.77		

Appendix 10 Binomial Table

Binomial probabilities: $\binom{n}{x} p^x (1-p)^{n-x}$

		p										
n	x	0.1	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.75	0.8	0.9
1	0	0.900	0.800	0.750	0.700	0.600	0.500	0.400	0.300	0.250	0.200	0.100
	1	0.100	0.200	0.250	0.300	0.400	0.500	0.600	0.700	0.750	0.800	0.900
2	0	0.810	0.640	0.563	0.490	0.360	0.250	0.160	0.090	0.063	0.040	0.010
	1	0.180	0.320	0.375	0.420	0.480	0.500	0.480	0.420	0.375	0.320	0.180
	2	0.010	0.040	0.063	0.090	0.160	0.250	0.360	0.490	0.563	0.640	0.810
3	0	0.729	0.512	0.422	0.343	0.216	0.125	0.064	0.027	0.016	0.008	0.001
	1	0.243	0.384	0.422	0.441	0.432	0.375	0.288	0.189	0.141	0.096	0.027
	2	0.027	0.096	0.141	0.189	0.288	0.375	0.432	0.441	0.422	0.384	0.243
	3	0.001	0.008	0.016	0.027	0.064	0.125	0.216	0.343	0.422	0.512	0.729
4	0	0.656	0.410	0.316	0.240	0.130	0.063	0.026	0.008	0.004	0.002	0.000
	1	0.292	0.410	0.422	0.412	0.346	0.250	0.154	0.076	0.047	0.026	0.004
	2	0.049	0.154	0.211	0.265	0.346	0.375	0.346	0.265	0.211	0.154	0.049
	3	0.004	0.026	0.047	0.076	0.154	0.250	0.346	0.412	0.422	0.410	0.292
	4	0.000	0.002	0.004	0.008	0.026	0.063	0.130	0.240	0.316	0.410	0.656
5	0	0.590	0.328	0.237	0.168	0.078	0.031	0.010	0.002	0.001	0.000	0.000
	1	0.328	0.410	0.396	0.360	0.259	0.156	0.077	0.028	0.015	0.006	0.000
	2	0.073	0.205	0.264	0.309	0.346	0.312	0.230	0.132	0.088	0.051	0.008
	3	0.008	0.051	0.088	0.132	0.230	0.312	0.346	0.309	0.264	0.205	0.073
	4	0.000	0.006	0.015	0.028	0.077	0.156	0.259	0.360	0.396	0.410	0.328
	5	0.000	0.000	0.001	0.002	0.010	0.031	0.078	0.168	0.237	0.328	0.590
6	0	0.531	0.262	0.178	0.118	0.047	0.016	0.004	0.001	0.000	0.000	0.000
	1	0.354	0.393	0.356	0.303	0.187	0.094	0.037	0.010	0.004	0.002	0.000
	2	0.098	0.246	0.297	0.324	0.311	0.234	0.138	0.060	0.033	0.015	0.001
	3	0.015	0.082	0.132	0.185	0.276	0.313	0.276	0.185	0.132	0.082	0.015
	4	0.001	0.015	0.033	0.060	0.138	0.234	0.311	0.324	0.297	0.246	0.098
	5	0.000	0.002	0.004	0.010	0.037	0.094	0.187	0.303	0.356	0.393	0.354
	6	0.000	0.000	0.000	0.001	0.004	0.016	0.047	0.118	0.178	0.262	0.531
7	0	0.478	0.210	0.133	0.082	0.028	0.008	0.002	0.000	0.000	0.000	0.000
	1	0.372	0.367	0.311	0.247	0.131	0.055	0.017	0.004	0.001	0.000	0.000
	2	0.124	0.275	0.311	0.318	0.261	0.164	0.077	0.025	0.012	0.004	0.000
	3	0.023	0.115	0.173	0.227	0.290	0.273	0.194	0.097	0.058	0.029	0.003
	4	0.003	0.029	0.058	0.097	0.194	0.273	0.290	0.227	0.173	0.115	0.023
	5	0.000	0.004	0.012	0.025	0.077	0.164	0.261	0.318	0.311	0.275	0.124
	6	0.000	0.000	0.001	0.004	0.017	0.055	0.131	0.247	0.311	0.367	0.372
	7	0.000	0.000	0.000	0.000	0.002	0.008	0.028	0.082	0.133	0.210	0.478

(continued)

Binomial probabilities:

$\binom{n}{x} p^x(1-p)^{n-x}$

n	x	p = 0.1	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.75	0.8	0.9
8	0	0.430	0.168	0.100	0.058	0.017	0.004	0.001	0.000	0.000	0.000	0.000
	1	0.383	0.336	0.267	0.198	0.090	0.031	0.008	0.001	0.000	0.000	0.000
	2	0.149	0.294	0.311	0.296	0.209	0.109	0.041	0.010	0.004	0.001	0.000
	3	0.033	0.147	0.208	0.254	0.279	0.219	0.124	0.047	0.023	0.009	0.000
	4	0.005	0.046	0.087	0.136	0.232	0.273	0.232	0.136	0.087	0.046	0.005
	5	0.000	0.009	0.023	0.047	0.124	0.219	0.279	0.254	0.208	0.147	0.033
	6	0.000	0.001	0.004	0.010	0.041	0.109	0.209	0.296	0.311	0.294	0.149
	7	0.000	0.000	0.000	0.001	0.008	0.031	0.090	0.198	0.267	0.336	0.383
	8	0.000	0.000	0.000	0.000	0.001	0.004	0.017	0.058	0.100	0.168	0.430
9	0	0.387	0.134	0.075	0.040	0.010	0.002	0.000	0.000	0.000	0.000	0.000
	1	0.387	0.302	0.225	0.156	0.060	0.018	0.004	0.000	0.000	0.000	0.000
	2	0.172	0.302	0.300	0.267	0.161	0.070	0.021	0.004	0.001	0.000	0.000
	3	0.045	0.176	0.234	0.267	0.251	0.164	0.074	0.021	0.009	0.003	0.000
	4	0.007	0.066	0.117	0.172	0.251	0.246	0.167	0.074	0.039	0.017	0.001
	5	0.001	0.017	0.039	0.074	0.167	0.246	0.251	0.172	0.117	0.066	0.007
	6	0.000	0.003	0.009	0.021	0.074	0.164	0.251	0.267	0.234	0.176	0.045
	7	0.000	0.000	0.001	0.004	0.021	0.070	0.161	0.267	0.300	0.302	0.172
	8	0.000	0.000	0.000	0.000	0.004	0.018	0.060	0.156	0.225	0.302	0.387
	9	0.000	0.000	0.000	0.000	0.000	0.002	0.010	0.040	0.075	0.134	0.387
10	0	0.349	0.107	0.056	0.028	0.006	0.001	0.000	0.000	0.000	0.000	0.000
	1	0.387	0.268	0.188	0.121	0.040	0.010	0.002	0.000	0.000	0.000	0.000
	2	0.194	0.302	0.282	0.233	0.121	0.044	0.011	0.001	0.000	0.000	0.000
	3	0.057	0.201	0.250	0.267	0.215	0.117	0.042	0.009	0.003	0.001	0.000
	4	0.011	0.088	0.146	0.200	0.251	0.205	0.111	0.037	0.016	0.006	0.000
	5	0.001	0.026	0.058	0.103	0.201	0.246	0.201	0.103	0.058	0.026	0.001
	6	0.000	0.006	0.016	0.037	0.111	0.205	0.251	0.200	0.146	0.088	0.011
	7	0.000	0.001	0.003	0.009	0.042	0.117	0.215	0.267	0.250	0.201	0.057
	8	0.000	0.000	0.000	0.001	0.011	0.044	0.121	0.233	0.282	0.302	0.194
	9	0.000	0.000	0.000	0.000	0.002	0.010	0.040	0.121	0.188	0.268	0.387
	10	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.028	0.056	0.107	0.349
11	0	0.314	0.086	0.042	0.020	0.004	0.000	0.000	0.000	0.000	0.000	0.000
	1	0.384	0.236	0.155	0.093	0.027	0.005	0.001	0.000	0.000	0.000	0.000
	2	0.213	0.295	0.258	0.200	0.089	0.027	0.005	0.001	0.000	0.000	0.000
	3	0.071	0.221	0.258	0.257	0.177	0.081	0.023	0.004	0.001	0.000	0.000
	4	0.016	0.111	0.172	0.220	0.236	0.161	0.070	0.017	0.006	0.002	0.000
	5	0.002	0.039	0.080	0.132	0.221	0.226	0.147	0.057	0.027	0.010	0.000
	6	0.000	0.010	0.027	0.057	0.147	0.226	0.221	0.132	0.080	0.039	0.002
	7	0.000	0.002	0.006	0.017	0.070	0.161	0.236	0.220	0.172	0.111	0.016
	8	0.000	0.000	0.001	0.004	0.023	0.081	0.177	0.257	0.258	0.221	0.071
	9	0.000	0.000	0.000	0.001	0.005	0.027	0.089	0.200	0.258	0.295	0.213
	10	0.000	0.000	0.000	0.000	0.001	0.005	0.027	0.093	0.155	0.236	0.384
	11	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.020	0.042	0.086	0.314

(continued)

Binomial probabilities:

$$\binom{n}{x} p^x(1-p)^{n-x}$$

		p										
n	*x*	0.1	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.75	0.8	0.9
15	0	0.206	0.035	0.013	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1	0.343	0.132	0.067	0.031	0.005	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.267	0.231	0.156	0.092	0.022	0.003	0.000	0.000	0.000	0.000	0.000
	3	0.129	0.250	0.225	0.170	0.063	0.014	0.002	0.000	0.000	0.000	0.000
	4	0.043	0.188	0.225	0.219	0.127	0.042	0.007	0.001	0.000	0.000	0.000
	5	0.010	0.103	0.165	0.206	0.186	0.092	0.024	0.003	0.001	0.000	0.000
	6	0.002	0.043	0.092	0.147	0.207	0.153	0.061	0.012	0.003	0.001	0.000
	7	0.000	0.014	0.039	0.081	0.177	0.196	0.118	0.035	0.013	0.003	0.000
	8	0.000	0.003	0.013	0.035	0.118	0.196	0.177	0.081	0.039	0.014	0.000
	9	0.000	0.001	0.003	0.012	0.061	0.153	0.207	0.147	0.092	0.043	0.002
	10	0.000	0.000	0.001	0.003	0.024	0.092	0.186	0.206	0.165	0.103	0.010
	11	0.000	0.000	0.000	0.001	0.007	0.042	0.127	0.219	0.225	0.188	0.043
	12	0.000	0.000	0.000	0.000	0.002	0.014	0.063	0.170	0.225	0.250	0.129
	13	0.000	0.000	0.000	0.000	0.000	0.003	0.022	0.092	0.156	0.231	0.267
	14	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.031	0.067	0.132	0.343
	15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.013	0.035	0.206
20	0	0.122	0.012	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1	0.270	0.058	0.021	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.285	0.137	0.067	0.028	0.003	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.190	0.205	0.134	0.072	0.012	0.001	0.000	0.000	0.000	0.000	0.000
	4	0.090	0.218	0.190	0.130	0.035	0.005	0.000	0.000	0.000	0.000	0.000
	5	0.032	0.175	0.202	0.179	0.075	0.015	0.001	0.000	0.000	0.000	0.000
	6	0.009	0.109	0.169	0.192	0.124	0.037	0.005	0.000	0.000	0.000	0.000
	7	0.002	0.055	0.112	0.164	0.166	0.074	0.015	0.001	0.000	0.000	0.000
	8	0.000	0.022	0.061	0.114	0.180	0.120	0.035	0.004	0.001	0.000	0.000
	9	0.000	0.007	0.027	0.065	0.160	0.160	0.071	0.012	0.003	0.000	0.000
	10	0.000	0.002	0.010	0.031	0.117	0.176	0.117	0.031	0.010	0.002	0.000
	11	0.000	0.000	0.003	0.012	0.071	0.160	0.160	0.065	0.027	0.007	0.007
	12	0.000	0.000	0.001	0.004	0.035	0.120	0.180	0.114	0.061	0.022	0.000
	13	0.000	0.000	0.000	0.001	0.015	0.074	0.166	0.164	0.112	0.055	0.002
	14	0.000	0.000	0.000	0.000	0.005	0.037	0.124	0.192	0.169	0.109	0.009
	15	0.000	0.000	0.000	0.000	0.001	0.015	0.075	0.179	0.202	0.175	0.032
	16	0.000	0.000	0.000	0.000	0.000	0.005	0.035	0.130	0.190	0.218	0.090
	17	0.000	0.000	0.000	0.000	0.000	0.001	0.012	0.072	0.134	0.205	0.190
	18	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.028	0.067	0.137	0.285
	19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.021	0.058	0.270
	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.012	0.122