Sustainable Design Education

Learning strategies for multidisciplinary education of undergraduates and professionals

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Abstract

The concept of sustainable design as a specialism within design, business and manufacture is not a new one. Writers and educators such as Victor Papanek (Papanek 1971) and Buckminster Fuller (Fuller and Snyder 1969) were advocating a change in the way we taught students how to design and look at the world in which they live. In parallel with this, many other experts (Carson 1962; Lovelock 1979) were highlighting the difficulties being caused by industrialisation and global trade in the natural environment. Issues such as the dramatic impact of the global population on ecosystems; the strains on the global and local economic systems and the challenges meted by social inequity were starting to be raised by scientists, economists and even designers as early as the 1960s. These are now finally accepted as real problems for today's students and professionals and for the world as a whole. They now provide clear opportunity both to graduates and to businesses as fields in which they can provide and develop expertise with a view to mitigating past and future problems.

This research grew out of an opportunity to examine how students and professionals learn to contextualise their design training through a sustainable design lens. Over a five year period from 2004-09 the research sought to evaluate how the learner understands and applies their knowledge and skills and to begin the process of developing a sustainable design mindset. Through the development of a series of case studies the research goes on to develop learning strategies that can assist the learner to work in a multidisciplinary environment and to develop a sustainable literacy with their colleagues from non design disciplines.

The work outlined here deals with how undergraduate students learn about sustainable design in a studio based environment over an extended period. It looks at the use of e-learning, multidisciplinary project work, live projects and the mixing students with professionals all through the vehicle of sustainable design.

The research also develops a number of strategies for assisting both SME (Small and Medium Enterprises) and practicing design professionals to learn about sustainable design. These strategies encourage the professionals to look at sustainability in a holistic manner and to develop a personal understanding about how it can influence their business and their design practice.

The principal research question is: *How can the third level effectively educate students, SMEs and professionals in sustainable design so as to be able to apply their knowledge, skills and competencies to design and industry practice in an effective manner within a complex and rapidly changing world paradigm?*

This body of research is a first comprehensive comparison of how undergraduate students, SME professionals and design professionals learn about sustainable design. It develops a number of learning strategies and proposes a sustainable design learning model based on the findings of the applied research.

Publications resulting from the research:

Peer Reviewed Journals:

1) Re-thinking design education - sustainable design education as a new lens by which to view design history.
   Fahey,T., de Eyto A., 2009. *Design philosophy papers, Australia.*
   (Paper in press July 2009).

2) Strategies for developing sustainable design practice for students and SME professionals.
   de Eyto, A., Mc Mahon, M., Hadfield M., Hutchings M., 2008.
   European journal of engineering education, EJEE special issue on sustainable development in engineering education. Volume 33, Issue 3, 2008, P. 331 – 342.

International Conference Presentations and Proceedings:

1) Developing sustainable design thinking interdisciplinary education case studies and methods for students and professionals.
   de Eyto, A., 2008. *Podscape for DEEDS (Design Education Sustainability), University of Brighton: '360^{o} – Charting new territory in sustainable design education' 18-20th September 2008*.

2) Animating sustainable design - interdisciplinary education methods for students and professionals.
   de Eyto, A., Hadfield, M., Hutchings, M., 2008. *4th EESD (Engineering education for sustainable development) conference, September 2008, Graz, Austria.*
   (Note: this paper was delivered as a keynote plenary session at the conference by invitation).

3) Connecting silos - ways to facilitate multidisciplinary learning for sustainable development.
   de Eyto, A., de Werk, G., 2008. 4th *EESD (Engineering education for sustainable development) conference, September 2008, Graz, Austria.*

4) Greening the emerald isle.
   de Eyto, A., Mc Mahon, M., 2007. *Sustain 07 conference, The 5th international conference on design and manufacture for sustainable development Loughbourogh University, UK, 2007.*

5) Greening the celtic tiger- Sustainable design and innovation for Ireland.
de Eyto, A., Mc Mahon, M., Van Lennep Hyland, E., 2007.
International research conference on sustainable development, Vasteras, Sweden, November 2007.

6) Teaching and learning strategies for introducing sustainable design practice to students and professionals.
de Eyto, A., Hadfield, M., Hutchings, M., 2006. *3rd EESD (Engineering education for sustainable development) conference, 2006, Lyon, France*, P.11
(Note; this paper won the Leo Jansen prize for the best paper at the conference).

7) Shaping sustainable professionals - the need to adapt learning processes by involving students, the steps that have to be taken.
de Werk, G., de Eyto, A., Cruz, Y., Rei, J., 2006, *3rd EESD (Engineering education for sustainable development) conference, 2006, Lyon, France,* P.56.

8) Learning strategies in sustainable design for students and professionals.
de Eyto, A., Hadfield, M., Hutchings, M., 2005. *Education for sustainable development: Graduates as global citizens conference.* Bournemouth University, UK, 12th and13th September 2005.

Professional Journals:

1) Our heads are round - Sustainable design or just the reframing of good design?
de Eyto, A., 2008, Creative Axis, *IDI (Institute of Designers in Ireland) journal.*

2) Sustainable Innovation through Design - An unprecedented opportunity.
de Eyto, A., 2007, Creative Axis, *IDI (Institute of Designers in Ireland) journal.*

Table of Contents

List of Figures:

List of Tables

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Glossary

Acronyms:

(BU) Bournemouth University

(C to C) Cradle to Cradle - Considering the lifecycle of the product from conception to re-conception (as distinct from Cradle to Grave) coined by Braungart and Mc Donnagh.

(C to G) Cradle to Grave - Considering the lifecycle of the product from conception to end of life.

(CPD) Continuing Professional Development - The continuation of formal and informal education while in a professional role.

(DEC) Design Engineering and Computing- School within Bournemouth University

(DfE) Design for Environment- Interchangeable with eco design

(DfS) Design for Sustainability- Used as a subtly differentiation from Sustainable Design

(HDP) Honours Degree Project

(HE) Higher Education- University and IoT education.

(ICT) Information and Communication Technology

(ID) Industrial Design -The design of products and systems for mass or batch production with a strong emphasis on function, form, interface and the user.

(IoTs) Institutes of Technology - Technologically-focused third and fourth level institutes within Ireland offering certificates, diplomas and bachelor, master and doctoral degrees. When used with name referred to as ITs. e.g. IT Carlow, IT Sligo

(IT)- Information Technology.

(LCA) Lifecycle Analysis - The process of analysing the impact (environmental, social and/or economic) of a product using metrics, typically for four major phases: production, distribution, usage and end of life.

(LCD) Lifecycle Design - As per Eco Design but used more in North America as a descriptor.

(LCM) Lifecycle Marketing - Marketing the product with an emphasis on the lifecycle.

(LCP) Lifecycle Pricing - Considering the cost of ownership through the full lifecycle of the product

(LCT) Lifecycle Thinking-The conscious inclusion of the lifecycle of the product in the design process.

(PD) Product Design - The design of more technical products with an emphasis on engineering and technology (interchangeable with ID depending on geography and discipline focus).

(PSS) Product Service System - Referring to the design and implementation of the full service around a product, not solely the product.

(SD) Sustainable Design.

(SDI) Sustainable Design Innovation -Level 9 masters module and CPD course created at IT Carlow.

(SME) - Small and Medium Enterprise.

(SPSS) Sustainable Product Service System- As per PSS but with an emphasis on the sustainability of the system.

(VLE) Virtual Learning Environment -In the context of this research a proprietary IT package called *Blackboard* was used (Blackboard 2009).

Definitions:

Cherry Picking - The practice of selecting the best examples of any given solutions so as to show high end results.

Downcycling- Refers to the waste stream; to create a new material that has inferior qualities to the original material.

Eco Design - A design process that considers the environmental impacts associated with the product through its entire life. Synonymous with DfE and LCA

Fourth Level - Also known as Post-graduate Study (normally at Masters, PhD or Post Doc. Level).

Green Design - A design process which focuses on dealing with individual environmental impacts rather than the entire life of the design.

Greenwash - The practice of covering over one's poor environmental credentials with positive (usually shallow) advertising.

Sounding Board - A term used to describe a person or a team who are used as a type of bounce back, allowing the person talking to see how their ideas sound.

Studio - A physical space designed to enable creative and applied activity, design work etc.

Sustainable Literacy - The ability to understand the specialist language of sustainability.

Third Level - Also known as higher education (HE) (normally three to five years of study to bachelor's level degree).

1 Overview, Definitions and Context

1.1 Introduction

Sustainable development is one of the greatest challenges the world has had to face in recent history. It is clear that humankind cannot continue to grow its population and industrial systems without irreversible consequences. It is past the time for innovation to move towards sustainable development in all possible ways.

Sustainable development is an ideal that is an aspirational ideal, which many believe is ultimately unattainable - a moving goal post. Each time one of the major issues is tackled it is superseded by another. The complexity and interconnectness of the issues requires global co-operation and expertise that humankind has yet to develop. There would seem to be a limited window of opportunity within which to change the way that we affect our ecosystem, economic instability and social inequity. Some argue that the time has passed (Lovelock 2000; Lovelock 2009); some suggest that we can only make incremental improvements (Lomborg 2001) and others are more optimistic and suggest that we can shift the paradigm through design, technology, co-operation, political and social will (Chapman and Gant 2007; Fuad Luke 2009; Mao 2004).

The words used to describe the concept itself are a challenge. *Sustainability*- sustaining what? Human existence, natural ecosystems, the status quo - surely not the status quo? - that is where the problems arise. *Development*- Developing economic and social systems but developing them towards what goal? How does one develop the natural environment? It is self regulating, self balancing and arguably does not need development until we introduce humans in to the equation. All these words have connotations that cause difficulty or opportunity in some form; some are more optimistic and aspirational, others pessimistic and hopeless. All depend on the context. This research seeks to contextualise these words for use in the design environment and to develop the concept of sustainable literacy as a critical element of any designers skill set.

Sustainable design is only one of the constituent parts of the overall sustainable development ideal. It suggests that design can be sustainable in its iteration and in its intent. Sustainable design only has relevance when it fits within the concept of sustainable development. Sustainable design understanding is only meaningful when it takes multiple viewpoints into account and accommodates divergent opinion and balanced application, yet this does not stop the words being liberally used and applied to products and service systems that are clearly unsustainable.

Sustainable design thinking and practice are newly developing fields of specialism with unestablished boundaries. Eco design, socially responsible design and green design for the environment, seem to be encompassed within the sustainable design field but with clear limitations in their scope.

The challenge that education has is in animating and representing this diverse and little-established field for the learner and the teacher alike.

For sustainable design thinking and practice to effectively become a reality the third level sector and industry itself cannot continue educating professionals as they have done until now. Although the third level provides basic knowledge about environment, society and economy, knowledge won't be enough to handle the sustainable development challenges on its own. What is needed, are professionals that can look beyond current developments, outside prevailing systems, to unchain new developments towards sustainability. Today's students can, and must, be these future professionals and teachers. Developing skills, coping strategies, awareness, leadership, critical thinking, knowledge and competencies, which provide them with a broad range of tools with which to address the issues, is key. The next generation of designers and business decision makers need to develop this range to help them deal with the broad and varied issues around sustainable development. Many of these skills exist within 'good education' and 'good design' but have been reduced to 'nice to haves' within our traditional educational systems. This thesis contends that it is vitally important to facilitate the learners that will take on the mantle of deciding what key decisions to make in the future regarding the manufacture and design of consumer products that the world will use.

The research develops a series of learning strategies to assist this. It compares learning needs and learning styles for undergraduates, SME professionals and design professionals. It proposes an ideal learning model for sustainable design and shows how the application of this model can assist in developing holistic, educated and creative thinkers who are able to deal with a changing global design context.

1.2 Aims and Objectives

The research outlined in this thesis aimed to develop a considered approach to the education of undergraduate design students and the continuing education and professional development of professionals in sustainable design.

The objective of the work was to develop, propose and prove a strategy for the holistic education of undergrads, SMEs and professionals with respect to sustainable design.

Aims:

- To evaluate current practice and approaches in other Universities and HE institutions.
- To evaluate the needs of SME learners and Professionals with respect to SD
- To develop a practice focused approach based on other models
- To contextualise the learning approaches with respect to a rapidly changing paradigm
- To compare and contrast the learning strategies of undergrads, SMEs and Professionals and to show how they progress in their learning throughout their careers.

Objectives:

- To develop a strategy for holistic learning in Sustainable Design.
- To customise this strategy in to concrete learning methods for Undergraduates, SME's and Professionals
- To develop, manage and facilitate a series of exemplar case studies to illustrate the strategy.

1.3 Overview

The research undertook a study of sustainable industrial /product design education and continuing education in the Irish context. The research has investigated the current practices at undergraduate third level (this includes universities, institutes of technology and polytechnics). The research has also investigated continuing education at a local SME/ industry level (within the south east of Ireland) and has sought to test some of these models with respect to industrial design and SMEs locally. In addition the research has informed the pilot of the first CPD (continuing professional development) course in sustainable design in the country in collaboration with the Design Ireland 'Skillsnet' programme.

The overall study included an investigation of current and developing practices in countries such as the UK, USA, Netherlands, Spain, Australia and New Zealand, to provide a benchmark against international practice.

The scope of the research area was originally to examine the effectiveness of four principle strategies with respect to sustainable design education.
These were as follows: student directed project based learning; e-learning tools; workshop style learning for SMEs; joint seminar format learning for SMEs and students. These

strategies are presented as a series of case studies which in effect formed the boundaries of the primary research in the first three years and initially all background reading and study was focused to complement these areas (See Figure 1).

The initial case studies led to the development of a series of learning strategies or models for multidisciplinary education with respect to sustainable design and development. In this context multidisciplinary education is defined as the joint learning of students and/or professionals from multiple disciplines to enhance the learning experience of sustainable design and development. This included design, business, engineering, humanities and science disciplines at an undergraduate and postgraduate level but is not exclusive to these. In SME terms it included professionals from multiple professional spheres; manufacturing, services, business, research etc. In CPD terms the SDI (Sustainable Design Innovation) course has been developed to target ‘design’ professionals, this includes multiple specialities of architecture, product, fashion, graphic, materials, engineering and packaging design.

In the final two years the further development of the undergraduate learning strategies and the development of a CPD masters module for professionals formed the core elements of the research. It is intended that the findings of the research to date would assist others in developing sustainable design education capacity and more importantly in making the case for a new style of multidisciplinary learning to be facilitated in education.

The research is driven by a need to develop learning strategies and tools that allow the learners to adapt to an ever changing world. By the time many graduates complete their training the environmental, social and economic considerations that they had defined during their education will have already changed. Hence the need to develop a wide range of contextualised skills and knowledge. The emphasis and appetite for the application of sustainable design practice in industry and business is constantly shifting. There would seem to be a clear opportunity for graduates and business to capitalise on this change in attitude towards the social and environmental considerations of design and manufacture. However, the scientific evidence would indicate the urgent need to radically change our industry practice for the sake of current and future generations.

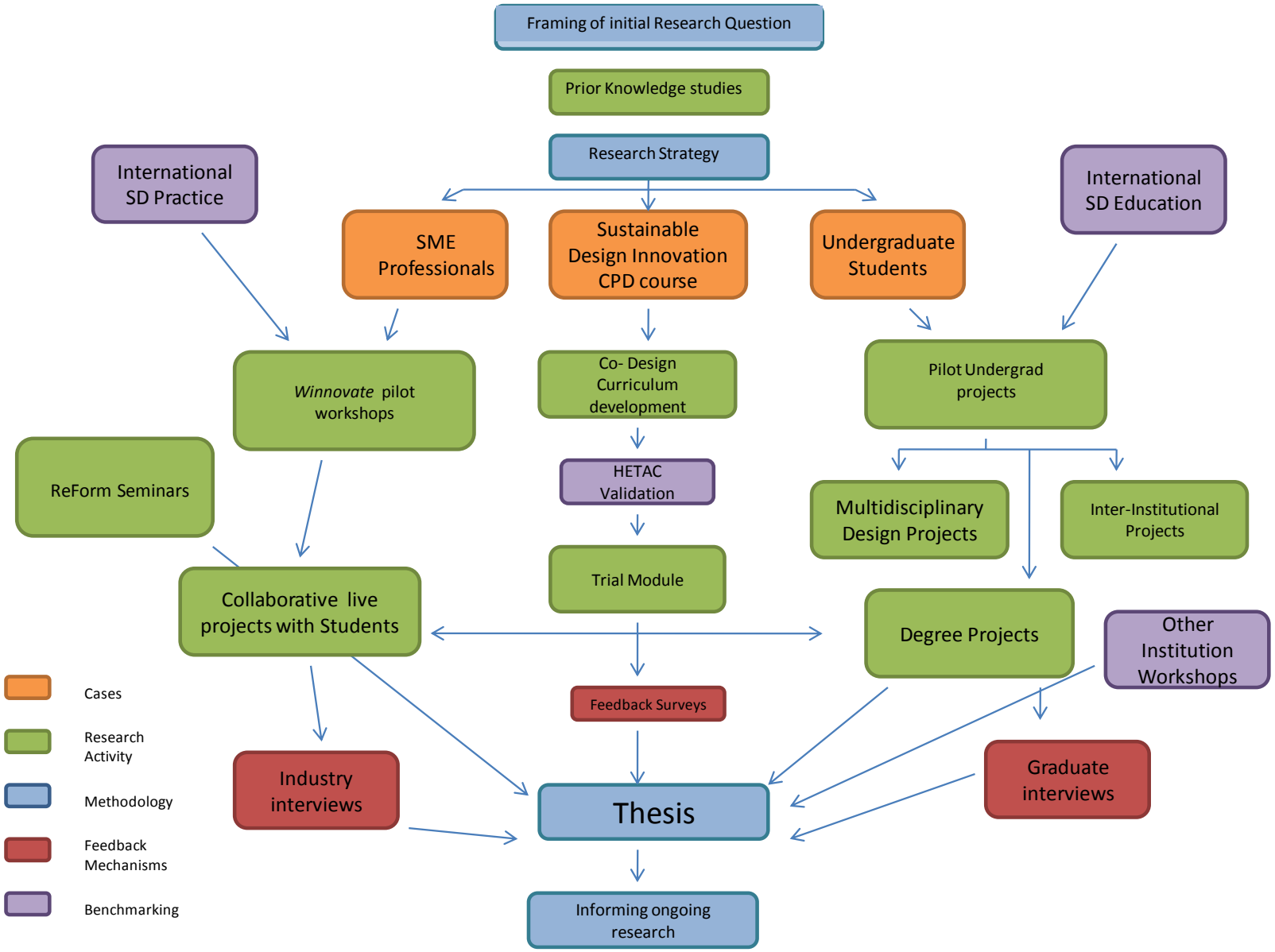


Figure 1: Key Elements of Research

1.4 Defining 'Sustainable Design'

The phrase 'sustainable design' is open to many interpretations. *Sustainability* means many things to many people. Economic and financial sustainability, system sustainability, environmental sustainability and social sustainability are all versions of sustainability. The word *Design* is widely used to describe many facets of creativity and human innovation. It is a sign of intent and is used commonly to describe the action of intended deliberate creation of an object, idea, system or aesthetic.

Design in this context refers to the activities of students, professional designers and businesses that lead to a conscious innovation of new products and product service systems. These products when released to the market have a direct impact on how we live our lives. They are generally mass or batch produced objects. They define in many cases our habits, user preferences, social interaction and ultimately contribute to our individuality (or lack of!) as humans. Design is the very deliberate process of seeking out different, new or just more effective ways of improving the efficacy of a product or system with respect to its users. The efficacy in the context of sustainability refers to the environmental, social and economic benefit of a product or system. If one assumes that design is a conscious action to attempt to change the status quo then it is fair to assume that it is possible to change a product or service for social, environmental or economic gain. Designers in this context have a responsibility to understand the complexities of a changing world, from an environmental and social point of view and to attempt to reflect that understanding in good design for that changed world. Good design is challenging, aesthetically pleasing, desirable, timeless, fit for purpose, engaging and it is emotive and affordable to the user. Good design 'sells' in the main and therefore is an economically viable and profitable activity for companies to engage in.

Many would argue that good design is the same as sustainable design but the research would suggest that there needs to be a subtle differentiation and that there is room for the description of sustainable design as a specific focus for designers to consider. 'Good' is too subjective a description in this case. One of the key research questions here is how can design be all of these things and also sustainable? How can educators instil in their students the knowledge and skills that are needed to design sustainably?

In the context of this body of research *sustainability* is defined using the often quoted United Nations Bruntland Report from 1987 which outlines a vision for sustainable development.

> Sustainable development '…is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland 1987)

Also

> Sustainability is about finding more socially cohesive, economically efficient and ecologically sound ways of producing and distributing existing resources (Rogers, 1997)

These quotes of course offer broad definitions of sustainable development; however in the design context sustainability and sustainable design are difficult terms to precisely define.

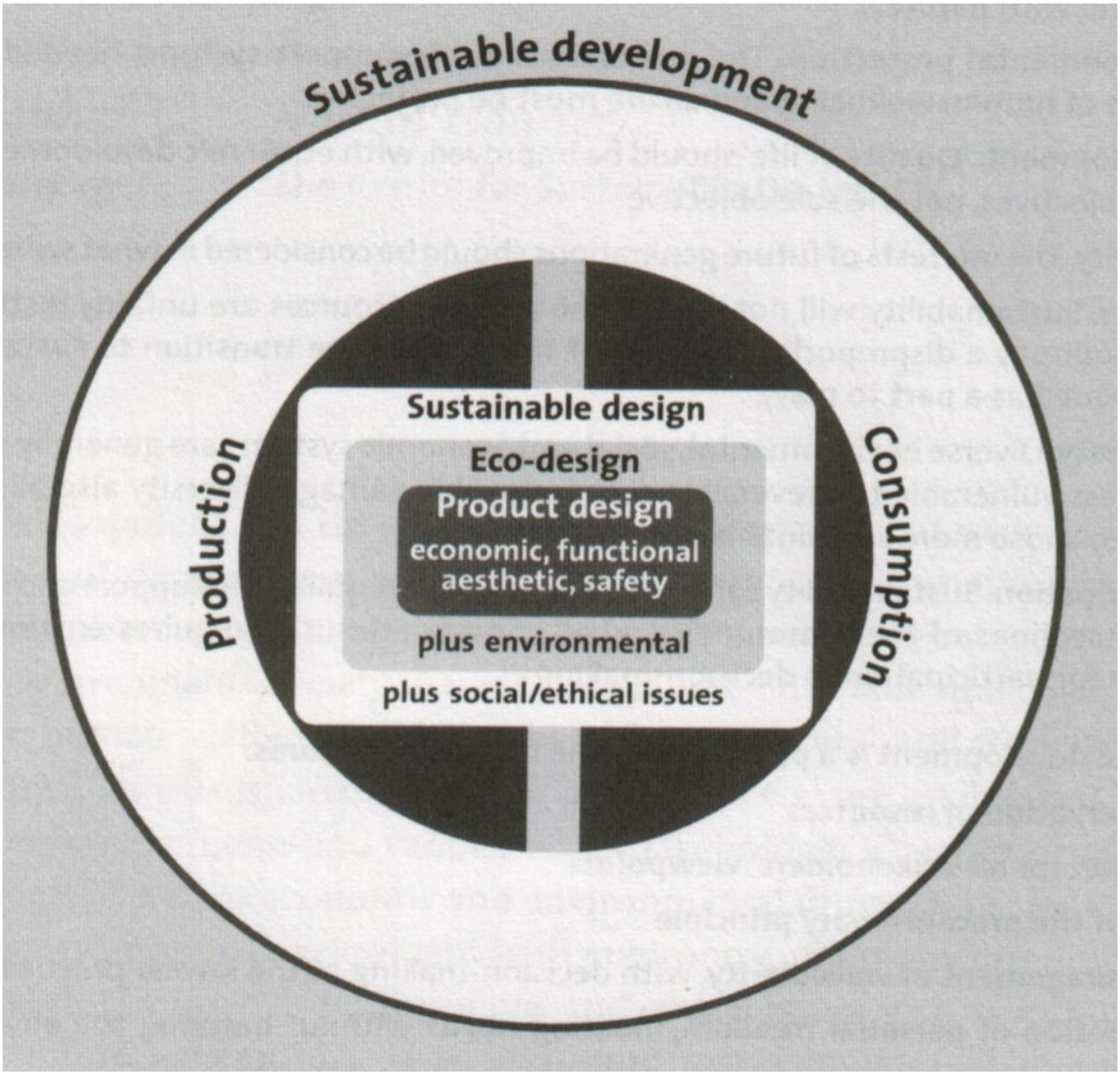


Figure 2: Sustainable Design as Understood by Tischner 2001

As per Tischner's diagram (Figure 2:) sustainable design fits outside the realm of traditional product design and traditional eco design (Tischner and Charter 2001)**.** It is not as all encompassing as sustainable development but it attempts to take sustainable development principles and ideology and apply them to the practice of product design. Sustainable design is not just eco design as this would imply a solely environmental focus neglecting the economic and social considerations. Sustainable design attempts to develop strategies for improving social equity, changing social behaviour with respect to products and systems and to influence consumer change through the product and its marketing.

From and economic perspective sustainable design addresses the viability and sustainability of a market. It seeks to broaden the challenge of the design from a solely visual and functional role to a vehicle for innovation and business development. Sustainable product designs offer a business the opportunity to tap new markets, gain competitive advantage, and remain economically viable in an increasingly global market.

Sustainable design attempts to include some or all the following considerations in a holistic manner:

- Social and environmental and legislative concerns
- Procurement and specification of appropriate materials and manufacturing processes
- LCA (Product Lifecycle Analysis), (LCT) Lifecycle Thinking, Cost of Ownership and LCP (Lifecycle Pricing)
- Social and Corporate Responsibility
- Packaging and waste considerations for products and service systems
- The marketing of sustainable design
- Sustainable Product Service Systems (SPSS)
- Ethically responsible trading and manufacture
- Energy use
- End of Life (EOL) considerations, materials reclaim, recycling, up cycling, rendering of hazardous materials, secondary use.
- User habits and Fit for purpose design
- Product or Service desirability and economic viability

The list above is not exhaustive but gives an outline the complexity of the term sustainable design.

1.5 Context

All of the definitions above assume that the ideal design or service system would be sustainable for a limited time period only. The system boundaries will change as social and environmental realities change; these along with the global economic climate only offer sustainable possibilities within a 30-50 year time period. As Rogers points out “after this all bets are off” (Rogers *et al.* 2007).

This research therefore offers learning strategies that build on the time bound skills and knowledge but assist the learner in identifying what is appropriate at any given time. The learner is encouraged to question and evaluate the uncertainty and the learning strategies give them the tools to adjust their skills and knowledge accordingly. The definitions above are offered as a current view of sustainable design. In the future this will no doubt have to be re-interpreted and even re-named.

The context for this research is predominantly applicable to the educational strategies that are used in the third level sector in Ireland. They obviously have relevance if applied to other European and ‘Western’ educational systems but the context is a critical boundary for the ideas presented here. The knowledge content of any of the case studies is highly localised. What is considered sustainable, for example, as a material, a process or a system in the Irish context will differ in another geographical location. Something that is economically viable in a global context may not be so in a localised context. Equally social norms and ethics differ widely and so local and global solutions for any socially sustainable concepts must be found. This is not to say that the options presented here could not be adapted for use in other educational contexts. If they were adapted they would need to take into account the local social, economic and environmental parameters.

One of the salient points emerging from this research is that students and professionals must be encouraged and facilitated to develop robust skills and knowledge for dealing with both local and global challenges.

1.5.1 The Irish Context

While Ireland may have the reputation of being an environmentally enlightened nation the reality is far from this, particularly in terms of sustainable design. Ireland has very little tradition in the field of design as it is known internationally; the education of Industrial or three dimensional design was only established after the mid 1960s following from the CTT (Córas Tráchtála) *‘Design in Ireland’* or ‘Scandinavian Report’ of 1962 (Franck *et al.* 1962). This report was the first of its kind and at state level it acknowledged the need for a greater

integration of design as a useful tool for economic and industrial development. It was extremely critical of what it saw as an under developed educational system in terms of industrial design. The authors of this report - all eminent design practitioners from three Scandinavian countries - proposed a new Irish Institute of Fine and Applied Arts. This, of course, did not come to pass as vested interests no doubt had sufficient interest to prevent such a radical departure. The first formal undergraduate courses in Industrial Design were not established until the 1973 with IT Carlow being the first followed by NCAD in 1976.
The Kilkenny Design Workshops (KDW) was established by in 1963 through the energies of WH Walsh of CTT and no doubt were influenced by the *Design in Ireland* Report. It provided a highly successful model for developing a broad selection of design disciplines from the industrial to the craft and visual communications fields. The KDW was unique in that it took the model of a private company which at the start relied almost exclusively on state capital to develop the premises and the initial human capital. The multidisciplinary nature of the KDW allowed for crafts persons, specialist designers and industry representatives to mix and develop work in an innovative manner. This in its own right created an environment where innovative design flourished and indigenous solutions to real Irish design needs were addressed. In a twenty-one year retrospective look at KDW written by Nick Merchant and Jeremy Addis the authors make the point that SMEs that worked with KDW were much more receptive to new ways of improving their business than would have been expected.(Merchant and Jeremy 1985). They go on to make the point that while the appearance of a product was often the initial reason for companies to engage with KDW-this opened up the broader possibilities for holistic design intervention once trust had been established. This trend is still to be observed twenty years on with the Winnovate Initiative as part of this research (described later in 4.7).

Even a recent article in 2006 in the New York Times extolling the quality and diversity of Irish design left little mark on the design Industry in Ireland. Finding the Irish slant, therefore poses a difficult challenge as there is little precedence for the integration of sustainability principles into design and industry practices. It is undeniable that education and re-education are essential if responsible behaviour is to become normative in the Irish design industry.

1.5.2 The 'Celtic Tiger' and its Demise

The economy of the Republic of Ireland (or the once famed 'Celtic Tiger') had experienced continuously high growth rates since the mid 1990s, after a period of severe difficulty in previous decades. This continued until the global economic downturn of 2008 which saw Ireland fall in to serious economic difficulties. The difficulties were not just as a result of the global downturn, most commentators would agree that an over exposure to the collapse in

the construction sector along with the banking crises that followed was inevitable at some stage. As a result of the boom however, Ireland managed for a period to exceed the average EU living standards, a situation which has reversed Ireland's traditional status as a peripheral European economy (Breathnach 1998). Ireland upon entering the E.E.C in 1972 was one of the poorest countries in the union; today it is one of the wealthiest. This trend automatically influences the environment in which the education around sustainable design takes place. It has a direct effect on the attitudes of the student and of the businesses representatives who participated in the research. It will be interesting to see in the future how the downturn affects this specific area of research.

1.5.3 Role of Design in the Irish economy

Design unfortunately has little history in Ireland. Traditionally the numbers of internationally recognised Industrial designers to emerge from Ireland have been few and far between (Caffrey 2000).Thankfully this situation is changing as Irish-educated designers are beginning to take their place on the international stage. Also the local design industry has seen rapid development and expansion in recent years with a number of design consultancies carrying out work for multi-national consumer product companies.

The importance of design in boosting the development of an economy is undeniable, not to mention the competitiveness afforded by clever design practices. On this premise many countries and regions have drawn up design policy programmes, including Ireland who in 1999 drafted a policy document entitled *Opportunities in Design: Strategies for Growth in the Irish Design Sector* (Bradley and Mc Gurk 1999) .The low level of design integration within locally owned Irish companies needs to be addressed and with increasing pressure from international markets the need for design specialisation has become even more pressing. Ireland is taking its time, unfortunately, catching up with the European trends having only in the last few years established government funded design centres in Shannon (Design Shannon, est. 2000), Sligo (Centre for Design Innovation Sligo, est. 2005) and Dublin (Design Ireland est. 2000). The remit of these groups is to increase awareness amongst Irish Industry about the implementation and utilisation of design as resource and strategic tool in product and service development, whilst also establishing a profile for Irish Design in the international context. There is recent evidence (2009) that some of these centres are already under threat due to lack of funding in the economic downturn.

It has already been recognised that the Sustainable Product and Systems Market offers huge potential for Irish businesses both locally and internationally. This new global market is estimated to grow to $700 billion by 2010 (Charter, 2006, Source UK DTI DEFRA,

Environmental Industries Unit [2006]) and it is the company's who take an active role now who will be at forefront of this industry. What is needed, are professionals that can look beyond current developments, outside prevailing systems, to unchain new developments towards sustainability. Today's students can, and must, be these future professionals. With a brand new view on the world, and the systems it consists of, they can change the current practices by designing new products and systems, changing people's minds, developing new strategies and policies and inspiring people to change(s) on local, national and international level. This task however poses a huge challenge to both students and tutors of design.

The research outlined in this thesis was conducted predominantly in an environment where both students and companies were at the height of what was locally known as the 'Celtic Tiger Boom' (variously acknowledged as between 1999 and 2007). This growth is due in no small part to international multi-national investment, which saw Ireland take a pivotal role in manufacturing goods for the global market. Foreign direct investment by companies such as Intel, Dell and Microsoft characterised the booming economy of the late 1990s and early 2000s. But with manufacturing patterns shifting eastwards, Ireland needed to refocus its emphasis on research and development if it was to increase its visibility up the value chain of product innovation:

> Our industrial and economic future rests in us becoming an innovation-driven Economy. Mr. Noel Treacy T.D., Minister for Science, Technology and Commerce (Treacy 2005)

Even though this investment by large international firms has played a large part in the growth of the 'Celtic Tiger' it is in fact smaller indigenous companies that still comprise the largest part of the Irish economy. In the years of affluence from around 1998-2006 one could observe that companies were less likely to seek innovative practice and new approaches to business (Mc Williams 2006).The energies were on keeping ahead of the global competitors and on trying to cleverly manoeuvre in the world of business rather than seek innovation and new product development.

In parallel with this the Irish education system also allowed for unprecedented access in terms of social status, affordability and availability of places. There was a distinct shift in access to third level over the period from about 1995 onwards. A report commissioned for the HEA (Higher Education Authority) indicated that the overall rate of admission to higher education had risen from 20% in 1980 to 46% in 1998.(Clancy and Wall 2000). Another study found that level to increase from 25% of School leavers in 1986 to 54% in 2003 (Guilfoyle 2008).This was followed by a significant further increase over the following years of the Celtic

tiger- for example in the academic year 2002/03, 129,283 individuals were enrolled as full-time students with an increase to 133,887 in 2003/04.There was also some shift in the age profile demographic during this period as there was a reduction of students of university going age in the population hence in the later years of the boom there was much greater choice for students leaving second level. This choice undoubtedly reflected in an increase in the competitive nature of Universities and IoTs (Institutes of Technology). Students across the board were being offered the ‘same for less’ in terms of degrees and time spent studying.

A degree of ‘dumbing down’ of curricula and delivery was also anecdotal across the third level sector in an effort to maintain retention of students.(O'Grady and Guilfoyle 2007) The factors contributing to these changes are complex and no single reason can be cited. Central government policy through the Department of Education and Science, HETAC (Higher Education and Training Awards Council) and the HEA (Higher Education Authority) is certainly a contributing factor. The pressure on Universities and IoTs to facilitate these growing numbers within the education has not always been met with a matching increase in funding.

Of course there have been benefits to the less fortunate in society in terms of allowing and encouraging access to third level where previously it was the domain of the wealthy or privileged. A third level qualification has become the benchmark for most western countries and Ireland was keen to follow this trend. Similar debates happen all over the world in terms of education and access to third level, countries and individual institutions have dealt with the issues around grade inflation in different manners. Matriculation exams for some of the higher profile universities in the US have become the norm as the high school or grad school system fails to give a clear picture of academic ability. In the UK for example the Imperial College has re-introduced recently its own entrance exams to combat the grade inflation at A-Level.

The question of academic ability and access are pertinent to the research mainly as a background to understanding that even during the short period of five years since the study began there has been a marked change in the ability of the students on the design courses at IT Carlow and elsewhere to deal with the complexities around sustainable design. It is unclear if this overall decline in ability is due solely to the student engagement and the average levels of literacy or if there has been a change in the commitment that the majority of students have to their chosen field of study. There are still similar amounts of students in every class who are committed, hard working and driven by motivation and a desire to learn

however there would seem to be a greater proportion who feel that third level is just an extension of second level - something that has to be endured.

1.5.4 Overview of Educational Institutions and SMEs

For the purposes of evaluating a sample of courses it was decided early on in the research to look at a cross section of three dimensional design courses. Five of the third level institutes (See Table 1) chosen in the Republic of Ireland offer 3D design degrees (including Product and Industrial Design).This is by no means a comprehensive reflection of all the courses that are on offer throughout the Republic however it was sufficient in terms of more detailed comparison. All the courses outlined here tend to follow the traditional design education route of problem and project-based learning. Of these five only two (University of Limerick, Institute of Technology Carlow) offer formal modules or courses in sustainability with a project/lecture mix being the preferred method of delivery in both cases. There are many reasons why sustainability is not taught in the other institutes, the main being that the expertise amongst the staff is not available. However, there is an obvious willingness amongst the lecturing staff in most cases to look externally for this expertise. In the final two years of the study there was some evidence of capacity building in NCAD (National College of Art and Design) and to a lesser extent Sligo IT in terms of sustainable design teaching.

Institution / Program	ITCarlow (Undergraduate courses)	University of Limerick	IT Sligo	NCAD (National College of Art and Design)	IT Carlow Winnovate (SMEs)	IT Carlow Sustainable Design Innovation /Skillsnet
Educational Offering	Offers Degree Courses in Industrial Design and Product Design Innovation	Offers a Degree Courses in Product Design and Technology	Offers Degree Courses in Industrial Design	Offers a Degree Course in Industrial Design	Structured CPD initiative (One off)	Masters Accredited CPD/ Skillsnet module
Focus / Speciality	Courses are business and Marketing biased with an emphasis on graduates working in SMEs and Multinationals	New Course with first year of Graduates in 2007, Engineering and Technology focused	General Industrial Design Courses servicing SMEs and Multinationals in North West of Ireland	Course is aesthetically focused with a strong emphasis on creativity	Broad range of Manufacturing Companies from Leisure, Medical, Waste Management and Service industries	Developing professional skills and knowledge in sustainable design
Sustainable Design (SD) application	SD built in to all elements of new PDI and ID course work.	Common SD Modules offered across a range of parallel courses	No obvious formal SD modules or delivery within course work	Some implementation of SD thinking within project work	Ad hoc approach to SD thinking and application in response to legislative change	Exclusive focus on Sustainable design
Multidisciplinary learning	Pilot projects implemented between Marketing/Design and also inter institutional projects with SD focus	Shared SD Module based learning in lecture delivery format	None observed	None observed	Regular interaction with multiple disciplines reflecting the nature of business	Mixed disciplines of designers - Architects, Industrial, Graphics, Furniture, Packaging
Level of knowledge with respect to SD (Based on PK questionnaire results)	Fair to Good depending on stage in course	Fair to Good depending on stage in course	Poor	Fair but dependent on personal interest and motivation	Fair but dependent on personal interest and motivation and experience of company.	Fair but dependent on personal interest and motivation

Table 1: Overview of Irish Product/Industrial Design Education Case studies

The third level institutes in Ireland visited for the purpose of this study were University of Limerick, the National College of Art and Design (NCAD) and the Institute of Technology Sligo. The Institute of Technology Carlow was of course the ongoing focus of three of the in depth studies.

To better gauge where both groups of students were placed in terms of their prior understanding of sustainable design it was prudent to undertake a Prior Knowledge survey. This survey had been used in previous research conducted on samples of Industry and IT Carlow design students and had proven useful as a benchmark from which to start activities.

The Prior Knowledge survey focuses mainly on the students understanding of key terminology and strategies on the environmental side of the sustainable design debate. The conclusions with respect to both of the student groups are outlined below.

In the case of the Sligo group the authors assumed no prior knowledge from students as their lecturers, in discussion, had stated that the students hadn't been exposed to any formal sustainability modules or projects. The actual survey indicated that the students in the main were familiar with broad public concern issues such as recycling, climate change, waste management etc. but not familiar with design strategies that might be useful in dealing with these issues. The students did rate the importance of SD highly in terms of both their own design careers and their personal lives. In almost all cases the students felt that it was very important to the viability of their future employers businesses.

Fast paced technological developments mean today's student's knowledge base and skill level is increasingly fast and furious. Lecturers find it difficult enough to keep abreast of existing design practices not to mention introducing a whole new sphere of knowledge to the students which is what would be involved with the introduction of sustainability concepts into the student curriculum.

In fact, research conducted by Muireann Mc Mahon a co-researcher at University of Limerick showed that for many educators some of the challenges they face in developing SD courses are:

> The complexity and multidimensionality of SD, it requires the development of new attitudes, knowledge, skills and sensitivities that are typically unfamiliar for design students. The diversity of students in terms of their design specialisations and the low level of appreciation of SD among many lecturers, often met with dismissive attitudes. The ongoing need to engage stakeholders in SD education and the difficulties of doing so .The need to strengthen systemic thinking and a holistic approach. The need to raise awareness for the challenges posed by globalisation. (Mc Mahon and de Eyto 2007).

It is clear from this overview that students and graduates need to be capable of understanding the relationship between knowledge and craftsmanship and social and environmental situations and the consequences of these. But they also need to be able to work in teams, think of solutions from different points of view, take opinions of all stakeholders into account and most of all develop solutions that really matter. This is aspiration is common to all the courses that were examined however the explicit introduction of sustainable design elements in to the curricula was not common. It is clear that aside from UL and IT Carlow the introduction of SD as a critical element to the design students skill or knowledge set is arbitrary at best.

2 Literature Review

2.1 Overview

There is a distinct gap in the crossover between the theory and ideology of current sustainable design thinking in one perspective, and its application to teaching and learning in the other. Many of the commentators in the theoretical realm have applied their thinking in their roles as consultants or industry practitioners but have made little comment on how they impart this expertise to others (Jones 2008; Mc Donnagh and Braungart 2002; Walker 2005). On the other side of the equation are the educators with an interest or speciality in the field of sustainable design within education (Bhamra 2007; Chapman and Gant 2007; Lewis *et al.* 2001; Papanek 1995). Many educational specialists base much of their curricula on the theoretical application of the knowledge and only these few writers seem to apply their experience in both fields. Too often commentators in the educational field have based their studies and curricula on out of date models and ideology that is not applicable to industry as a whole. It would seem that many of the educators still focus on incremental change and influence in the narrow realm of their specific disciplines and the curricula often reflect this approach (Richardson *et al.* 2005). Holistic, or joined up education, is the more difficult challenge facing education and the constraints of the traditional educational models referred to in the following sections mean that those developing new educational models or strategies have to work even harder at finding paths through and around the obstacles in addition to ensuring that the content and level of debate are kept at a high level.

The most influential literature in the field of sustainable design and education has been broken down here in to subsections below and further critical appraisal and comparison is provided at the conclusion of the chapter.

2.2 Sustainable Design Theory and Policy

It would be almost impossible to comprehensively account here for the huge range of opinion and thinking around sustainable design but the research to date has chosen to focus on a number of key writers in the field to reflect both the radical and the conservative ends of the field. The challenge with sustainability is in trying to reflect not just in the context of this research but also for the prospective student of sustainable design the broad range of expertise and opinion that exists. As sustainable design is complex it encompasses opinion and research from many design and non-design experts. Often researchers and theorist are at odds with each other in terms of where the focus should lie.

There is a constant struggle between both the general and the specific, the ideological and the practical.

2.2.1 Ideological/Radical

Ideologically writers and editors such as William Mc Donnagh and Michael Braungart (Mc Donnagh and Braungart 2002), and Bruce Mao (Mao 2004), are at the ideological end of the current debate on how sustainability should be interpreted. Others such as Stuart Walker (Walker 2006), Jonathan Chapman (Chapman and Gant 2007) and John Thackara (Thackara 2005), provide more in depth philosophical approaches to sustainability and how it impacts on design. There are multiple directions from which one can approach the impact of sustainability on design or indeed the impact of design thinking on sustainability.

John Thackara (Thackara 2005) and Jonathan Chapman (Chapman and Gant 2007) for example give an excellent overview of the complex world in which we live and work and they expresses the challenges of design and designers in influencing how this world Is shaped.

In *Cradle to Cradle* Mc Donnagh and Braungart make very cohesive arguments around the current and future use of raw materials. They introduce the ideal of a technological and a biological sphere of materials from which designers and manufacturers should choose carefully and design with the full lifecycle in mind (Mc Donnagh and Braungart 2002). They argue that mixing of these ‘nutrients’ is the single biggest issue around resource depletion. If we avoid making cocktails of complicated materials then we have the possibility to endlessly re-generate or re-use materials within the given sphere. The writers also make the point that the tendency for sustainable design thinkers to alienate themselves from mainstream commercialism and capitalist culture is rendering their arguments useless and academic. They advocate involvement and action with all sectors of industry and to work within the system of capitalism and market driven consumerism. They argue that for sustainability to be truly sustainable from an economic, social and environmental perspective it needs to have the market led impetus that is currently devoted to mass consumerism. They, unlike many other commentators, do not see sustainability as being contradictory to consumerism. Their work with companies such as Nike, Ford and Herman Miller all illustrate (at least at an ideological level) successful attempts to prove their theories and while much of their thinking is in line with other writers in the field it is refreshing to read a collaborative and proactive approach to the problems of sustainable design. Too often commentators tend to be negative towards the status quo and short on practical examples of how ideology can be implemented. Professor Michael Braungart of the EPEA was one of the keynote speakers at

the ReForm 08 seminar (as described in 5.4.1) and he gave some examples of how the thinking behind the *Cradle to Cradle* has developed since the writing of the book. There are some questions around the presentation of the *Cradle to Cradle* ideology and their over reliance on both Braungart and McDonagh as 'celebrity' experts within the field.

One can see parallels to the rise in popularity (and awareness) of the global warming debate through the medium of documentary film and through the celebrity status of Al Gore in *An Inconvenient Truth* (Guggenheim 2006). There can be an impression given by Braungart, Mc Donnagh and others that only high profile companies and projects deserve their attention. It is of course the large global clients that have the potential for greatest impact in terms of effectiveness in the SD arena but SMEs and local initiatives have equally beneficial effects if the practice can be communicated to them. Large corporations are also at greater risk of 'cherry picking' and 'greenwashing' to maximize on public relations leverage where SMEs rely much more on their direct customer relations and reputations.

In *Massive Change* (Mao 2004) the authors make a series of observations about contemporary culture and society as we move from a post industrial society to an information age and service led economy model. The arguments here illustrate how single stand alone solutions will become less and less effective and that a move to a more holistic and systems based approach is required. The various essays and case studies in *Massive Change* give us a broad overview of how a multidisciplinary approach to sustainable design and development is critical. Practical examples of innovation, energy policy, and usage, marketing, developing technologies and politics all have a place in the toolbox of a designer or engineer. The clear boundaries that once existed between professionals seem to be starting to blur as holistic thinkers work in multidisciplinary teams to solve systems based issues and problems. *Massive Change* does not solely focus on western economies but looks at the issues surrounding developing economies and cultures also and how to adequately cater for their very different needs.

There are limitations in the ideologies described here; they do apply directly to the research work in terms of raising the level of debate to a holistic and lateral thinking level and the case studies outlined provide the learners with real examples of ideology in practice but often they are limited by their 'big brand' status. It can be difficult for the novice sustainable designer to see the application of such knowledge in their immediate work. Many of the case studies advocate a full scale overhaul of systems thinking within companies and brands and these concepts are often beyond the current understanding or experience of a student or a small SME. A balance of practical applied tools and ideological drive are both needed. There is no

doubt that sustainable design is a complex practice and that if too much ideology is delivered from the offset in the learning strategies it can have a negative effect on the learner. It is not that the novice learner cannot handle more complex strategic thinking and even heavily ideological debate but the research has found that if too much is introduced at an early stage in the learning process it can have a confusing effect. It can be seen that in the observations from the joint seminar format (see 5.4) that bombarding the novice with huge ideological and ethical questions can often leave them depressed and despondent about how they can effectively influence change. It remains to be seen whether the ideological thinkers and practitioners from the current debate have a lasting impact on design activity in the future.

There are many theories on how design professionals should develop their concepts and products so as to ensure that sustainable thinking is at its core. In the main the focus for the past 40 years or so has been on environmental efficiency and the environmental impact of a product. The key writers in the field include Victor Papanek (generally considered as one of the originators of sustainable design thinking) and Buckminster Fuller(Fuller and Snyder 1969). Papanek's groundbreaking writing in *Design for the Real World* (Papanek 1971) received a mixed response from the design community worldwide. The arguments made in 1971 were of course topical and responding to the difficulties of mass consumerism and environmental degradation that were already well apparent. However, many design professionals at the time felt that Papanek's arguments were overly idealistic and had no place in a capitalist culture where industrial design was driven primarily by marketing and business acumen. On the other hand, Papanek was widely acclaimed as a lead thinker in the educational sphere and his texts continue to be standard reading in design curricula around the world. It is obvious that much of his idealism is easier to apply to an educational model as students and academics have this luxury while working within the walls of academia. It is fair to observe that the same disparity still exists between academia and industry today however sustainability has moved more centerstage over the past five to ten years and the disparities are easier to overcome.

Design for the real world was followed in 1995 by *The Green Imperative* (Papanek 1995) which focused on the growing need for designers to seriously take on board their moral and ethical responsibilities to design with environmental and social principles in mind. Papanek again was probably ahead of his contemporaries in raising issues around ethics and spirituality in design. He argued that if designers can include these issues in their design work that the sustainability of a product or an idea will be inherent by default.

With respect to education Papanek in both texts (Papanek 1971, 1995) argues the need for design and engineering to be as broadly taught as possible. He makes the argument that the specialities need to be introduced as early as possible in the educational curriculum. Papanek argues that design education needs to be for all and that much of the curriculum that we currently apply to third level design and engineering students could and should be introduced much earlier in primary and secondary school.

In the context of this research this work is invaluable as it outlines a lifetime of effort in attempting to implement sustainable design thinking at both an educational level and to a lesser extent in industry. It would seem that where Papaneks work fell short was in the broad market appeal of his strategies. The educational ideology while used in a number of third level courses did not receive broad acceptance and perhaps this was due to the overtly radical nature of the ideas. It could be said that Papanek's ideologies were ahead of their time and that a re-evaluation of them might be appropriate in the current world climate. From an educational perspective there is still a great deal of conservativism and even today it is difficult to radically change the structures and mechanisms that support curricula. The research has shown that even incremental changes to course design and CPD can be difficult to push through. This challenge will no doubt be exacerbated due to the current global economic downturn.

2.2.2 Pragmatic

Certain commentators have the ability and skill to communicate with the student, SME or design professional in a simple, clear and pragmatic manner. This skill has a much broader applied benefit when compared to the more ideological or radical approaches described above.

Design + Environment (Lewis *et al.* 2001) gives us a more up to date perspective on dealing with the environmental aspects of Sustainable design. In this case the authors aim to provide a practical guide to designing greener goods and this is based on the Australian and international experience gained through their work in consultancy and through RMIT (Royal Melbourne Institute of Technology). In their writing Lewis and Gertsakis along with their co-authors clearly classify and explain the key language terms and design methods involved. They use a series of excellent case studies to provide practical insights in to the use of LCA (Lifecycle analysis) tools, eco-design strategies, management of eco-design, and a range of specifics for product, furniture, packaging, and textiles designers. In all the book provides a really hands on approach which is also comprehensive in its dealing with the complex subjects. At a seminar in 2005 in SIAD (Surrey Institute of Art and Design) the researcher

had the opportunity to talk with John Gertsakis and he felt that even only four years on from publishing this book that much of the information was now outdated and perhaps some of the concepts were a little naïve. This was of interest as it illustrates how quickly even the most up to date experts in the field can fall out of touch with the economic, social and environmental realities of the day if they do not keep in touch with the current trends. Gertsakis is now exclusively involved with running his consultancy 'Product Ecology Ltd.' and provides hands-on technical expertise in eco-design for companies.

The discussion with Gertsakis also illustrates in the context of the research that knowledge is not everything; knowledge of processes, materials and even strategies is a transient thing. The ability to seek knowledge and ask the pertinent questions is a skill that students must learn and the application of this knowledge is where the interface happens with industry. Any learning strategies which leave this basic principle out of their equation are bound therefore to be less than effective.

Alistair Fuad-Luke has provided an excellent set of books from the *Eco-Design Sourcebook* to the latest thinking in *Design Activism* (Fuad-Luke 2002; Fuad-Luke 2009). This collection of work provides an extremely useful array of literature that both the student and educator alike can use as a source for inspiration and allow the learner to see how sustainable design principles can be applied in a more strategic role. In the sourcebook Fuad-Luke also provides some basic materials selection categories, simplified sustainable design philosophies, and real life case studies that help illuminate the often highly theoretical discourse that surrounds sustainable design. Again through both the ReForm seminars and the SDI masters module (described in 5.5.2), the researcher has had many opportunities to work with Fuad-Luke.

More recently Tracy Bhamra and Vicky Lofthouse of Loughborough University have published a book entitled *Design for Sustainability a Practical Approach* (Bhamra 2007). This work breaks down, in to logical groupings, the key approaches to sustainable design. These are supported by some excellent case studies that provide very useful and present practical case studies of how the theoretical approaches have been implemented. Much of the work is based on projects and research pieces developed at Loughborough; however these have broader appeal to design students and professionals alike. In addition, Lofthouse has also been responsible for the SDN (Sustainable Design Network) in the UK which has provided one network through which designers and educators can share experiences and work. This and other networks (described in 2.6) are critical to the sharing of experience and the collaboration that ensures new innovations in sustainable design education.

From a review of the important literature on sustainable design it is then important to link this with education.

2.3 Educational Theory and Practice

It is necessary as an integral part of the research to look at the various key writers in the field of educational theory (Barnett 1994; Bloom 1956; Jarvis and Griffin 2003; Kolb 1984; Orr 1992; Papanek 1971; Roberts 2004). These writers give the foundation for the educational strategies to be built upon. Many of these theories have been in place since the 1950s and yet much of their wisdom has still not been implemented in the wider third level environment. It would seem that there is educational theory on best practice in terms of pedagogy, andragogy and such like and conversely there is educational practice as it exists on the ground. The theorists illustrate the ideal forms of education and clearly demonstrate through case study and example how this might be applied to best effect but the practice of same seems generally to be restricted hugely by the economic, political and administrative pressures of individual institutions. Education at third level is the difficult balance between developing knowledge, skills and competencies and on the other hand maintaining funding, student numbers and business related relevance. There are new challenges becoming apparent even within the short five year timeframe of this research. The economic and financial constraints of education are changing in Ireland from a 'Free Fees' model of education to the prospect of the re-introduction of fees due to the economic downturn of 2008/09. This new development at the latter part of the research provides a whole new possible shift in context. With a return to fees based model there is a realisation that the funding of education will be different, participation less inclusive of all social sectors and certainly that the motivations of students will be altered slightly. This observation is offered as a context for the changing environment that Irish education now faces.

There are many levels of debate within educational theory and practice some highly academic and others highly applied and practical. The key aspects applicable to this research are in the areas of problem based learning (Papanek 1971), experiential learning (Kolb 1984) studio learning (Roberts 2004) and group learning (Tuckman 1965) as these apply directly to sustainable design.

It would seem that for sustainable design as a specialism to be truly effective in the world of business and manufacturing it needs to be taught in a holistic manner. Careful consideration needs to be given at all stages of syllabus development to the intended final outcome. I.e. what type of graduates or professionals do we want to produce? The syllabi, whether they

be a short course developed for CPD (continuing professional development) of business professionals, or for undergraduate or post graduate students all needs to be developed with the same specifics in mind, i.e. the application of knowledge for the betterment of society; the preservation of the natural environment and for equitable economic prosperity.

These are lofty goals but ultimately the failing of education in the new millennium would be to focus too much on singular objectives when it comes to undergraduate courses. Specific discipline research is critical of course as a means to exploring detail and creating innovation but it can be argued that this approach also has a place at an undergraduate level.

Anecdotally it would seem that many courses in Europe which are pitched as master's level are little more than an extension of an undergraduate degree with little genuine research and a continued reliance on prescribed course content.

In the context of sustainable design 'knowledge' is critical; knowledge of the terminology (language) of the field; knowledge of specific materials; processes; techniques that might be pertinent to the conception and manufacture of a product. Knowledge in this case is defined as:

> Those behaviours and test situations which emphasise the remembering either by recognition or recall, of ideas, material, or phenomena.
> (Bloom 1956)

The knowledge of terminology allows the user to converse effectively with their peers and to accurately describe complex scenarios or ideas that might otherwise not be easily explained in lay terms. The knowledge of specific facts helps in the abstraction of concepts or tasks and in communication of ideas. Knowledge of conventions, trends and classifications etc. are all equally important to the learning process.

In *Limits of Competence,* Barnett introduces the concept of 'Throwaway Knowledge' or the ability to discard knowledge in an effort to upload new more relevant or current knowledge (Barnett 1994). For sustainable design this idea is particularly useful as the boundaries of what is current are constantly shifting and knowledge of certain specifics such as the use of a particular polymer or a chosen energy source, might be considered most appropriate at the time of learning but by the time the user gets to a situation of application of this knowledge the polymer or energy source may well be outdated by a more appropriate alternative.

Skills are the ability to apply the knowledge to solve problems; some see critical thinking and reflective thinking, as abilities and skills but equally the ability to draw, communicate,

conceptualise and think laterally are all skills that are critical to sustainable design. The development of skills by the student allows the student to deal with any given problem with a toolbox at their disposal; they know what the tools are for, how to use them and as different problems arise they need to have the ability to use the appropriate tools for the given problem.

Sustainability by its nature requires a broad global thought process which considers not just the specifics of the given problem but also the wider consequences of any solution or decision. The difficulty with traditional education has been that it has increasingly compartmentalised and specialised the thought process. Knowledge becomes a commodity and specialist knowledge becomes increasingly valuable in this system. However it also causes a blinkered approach to a given problem. Design has traditionally sought to realise a lateral thinking approach and so it is not unusual for designers to consider a problem from a lateral or radical perspective before applying their knowledge and skills to tackle the problem. From an androgogical perspective this process has been observed in various manners (Bloom et al 1956).
Figure **3** illustrates how a student can deal with complex unfamiliar concepts as well as more familiar ones and still affect a solution of a given problem. The challenge with respect to sustainable design problem solving is in the area before Steps 1-5. A student's perception of a problem is key. Their knowledge will determine to a great extent, their perception of a problem and so the learner following a process of research can help expand that knowledge so as to address their perception of a problem at multiple levels. This research can be fact finding or just informing themselves of issues and problems, in either case it is intended to open their awareness and begin to develop their literacy (as described later in 7.1 and 2.4.3)

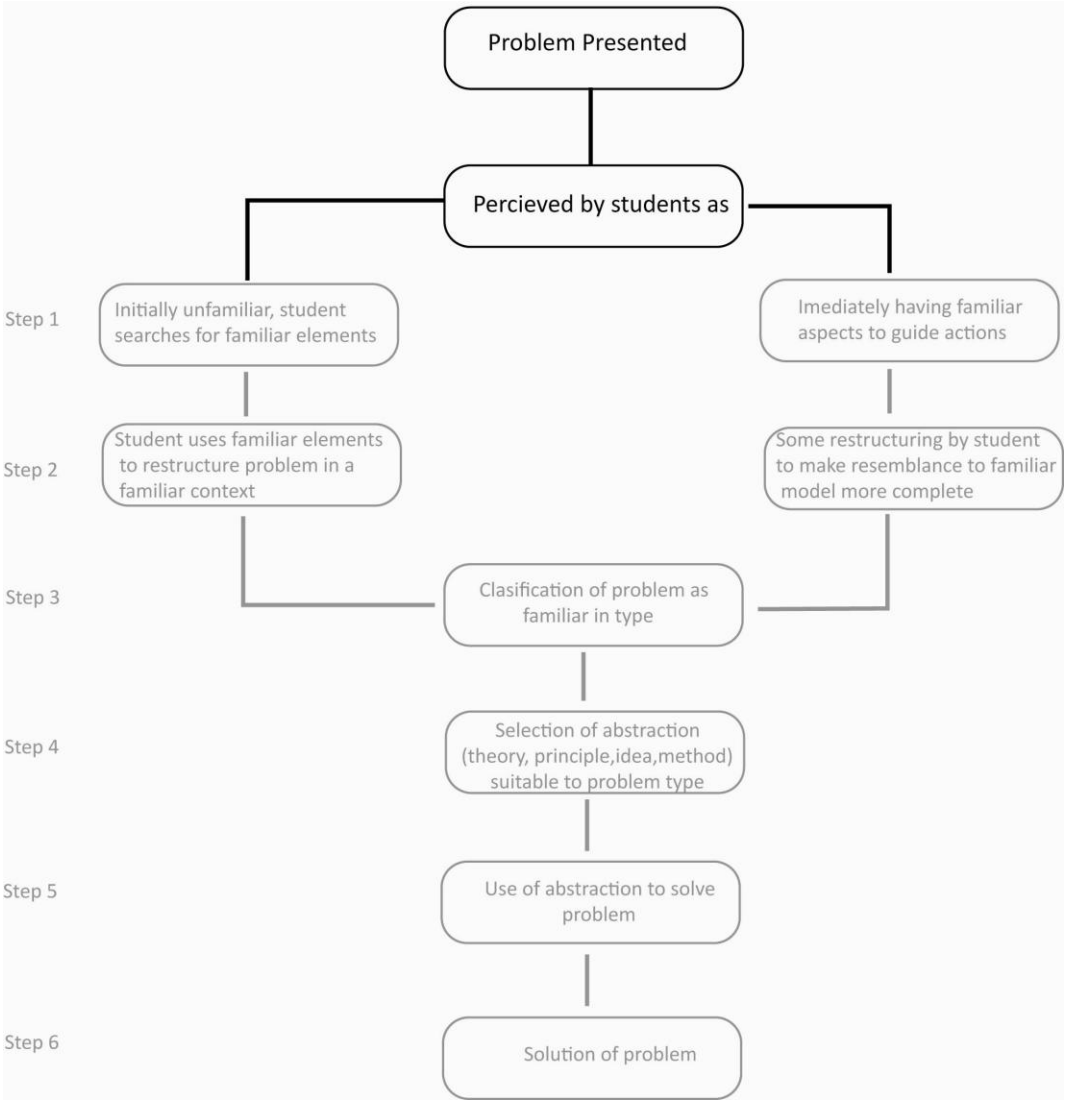


Figure 3: Bloom's Problem Solving Process (Bloom *et al.*1956)

- Perception of the problem is critical to sustainable design-

The scope of the research here involves multiple steps in Blooms' process. The fact that this process is linear in representation is a limitation as it suggests that little re-visiting of any of the stages occurs in the problem solving process. In sustainable design practice this can equally be limiting as the assumption is made that the problem is singular which is often not the case.

Kolb (1984) on the other hand provides us with a simplified version through his learning cycle diagram (Figure 4). While this is not intended to reflect the problem solving process it does

provide a more accurate response to the approach that this research is seeking to establish. The suggestion here is that the learning is cyclical and that there is constant room for new learning. All stages here are critical as a student or professional learns by doing and reviewing. Sustainable design as with all design practice is re-enforced constantly by the active experimentation and experiential phases.

This research seeks to implement all the stages outlined in a participant's education. With the undergraduate students it is the concrete experience phase of the cycle that can be the most difficult to implement. The studio based project work attempts to simulate much of this work but 'live' work outlined later in this document manages to achieve some of this ideal. On the other hand SME representatives often lack the experimentation and conceptualisation phases of Kolb's cycle and so the focus of the workshop based work with the SMEs has been to provide some of this to the learners.

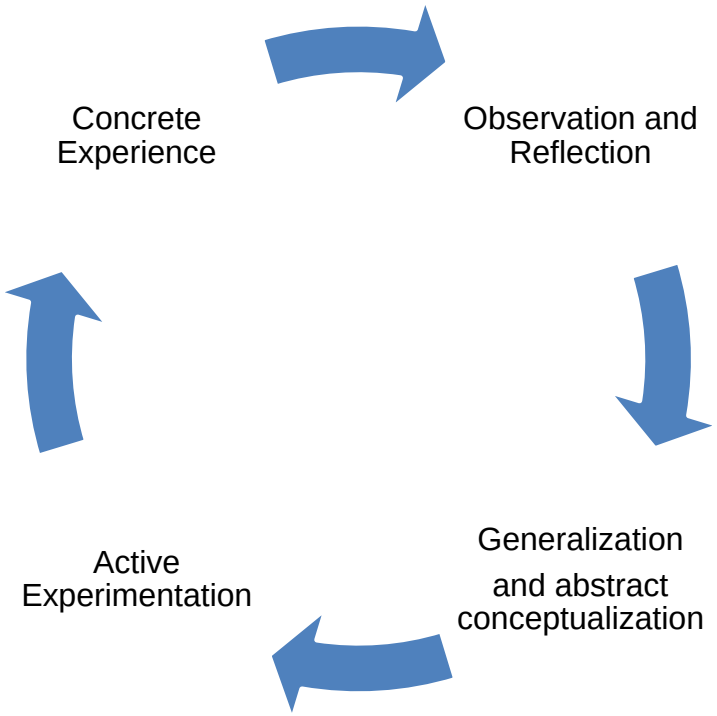


Figure 4: Kolb's Learning Cycle (Kolb 1984)

Figure 5: Felder-Silverman Model of Learning Dimensions

The learning styles proposed by Felder and Silverman (Felder and Silverman 1988) illustrate very well the different types of learner that need to be accounted for in any learning process (see Figure 5). They make this observation with respect to engineering education and they suggest that certain dimensions oppose their opposite. In sustainable design it is clearer that the learner needs to be able to work within multiple dimensions, i.e. the learner may need to learn through both verbal and visual input or they will develop an active and a reflective processing of information. The challenge is therefore to cater for specific learning dimensions that the learner normally responds to but also to develop their less used dimensions in order to give a more holistic skillset.

In *Design Research* (Laurel *et al* 2003) Rhea makes a case for divergent thinking before convergent thinking when it comes to tackling any given problem (see Figure 6). With respect to sustainable design thinking and practice there is an obvious requirement to think laterally (divergently) and holistically about issues and problems and then to converge that thinking in to pragmatic solutions. This model (although not cited as such) would seem to be based on the earlier model from 1971 by Arnold (see Figure 8).

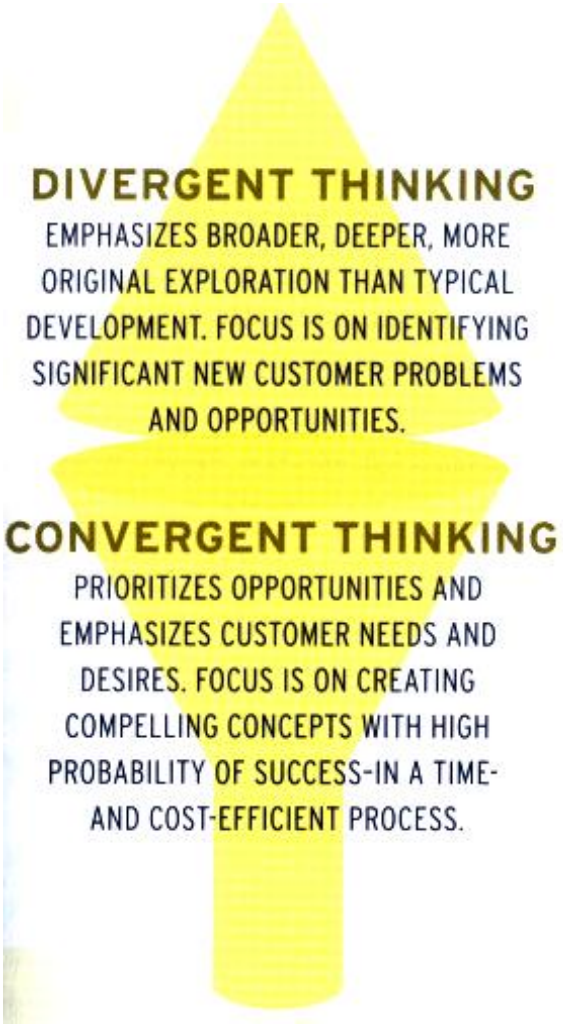


Figure 6: Rhea's design research model (Laurel et al 2003)

Albert Einstein is quoted as follows;

> The world will not evolve past its current state of crisis by using the same thinking that created the situation (in McDonagh and Braungart, 2002).

Incremental changes and improvements in energy efficiency, materials usage and consumer habits will no doubt improve our current environmental problems but it is widely predicted that we need a radical shift in thinking and practice as a species if we are to become truly sustainable. Weisacker proves with his I-PAT formula that small improvements will not save the world. We need radical system changes that decrease the environmental burden to half of what it is now within 50 years (Weisacker 1998).

As the research is focusing on how to better educate adults in third level and business persons in sustainable design it was important to look at the differences between educating adults and educating young people.

In 1967 Dr. Malcom Knowles proposed this difference and re-invented the term andragogy as distinct from pedagogy.(Knowles 1973) and also in (Jarvis et al, 2003)
Knowles' androgogical theory is based on four assumptions which differ from those of pedagogy: (1) changes in self-concept, (2) the role of experience, (3) readiness to learn, and (4) orientation to learning (see Figure 7).

It is apparent that this was a direct reaction the difficulties that pedagogical models were causing in the development of third level curricula. Knowles argues that adults are self directed unlike young people and so there is a need for their education to allow for this self direction. The facilitation of self direction if included in any model of sustainable design education could in theory have much deeper meaning as the student then develops a unique personal understanding and philosophy of what sustainable design means to them.

Figure 7: A visual representation of Malcom Knowles' Model of Andragogy

The alternative route is for the educator to prescribe the majority of what should be learnt thus producing a non thinking individual, perhaps only useful to a company or institution that wants passive automated workers. It is often muted in design circles that students do not really begin to learn until they have worked for a number of years in industry. Perhaps this is an indirect criticism of the design curricula which seek to teach the students skills and knowledge but often neglects to work on the practical application of these in a business orientated world. With this in mind it was important to look at the application of what Barnett describes as the difference between experiential learning and problem based learning (Barnett 1994). Experiential learning is described as off site work placement or practice for example which places the student in the business or commercial world. This has the benefits of allowing the student to experience all of the complex interactions that occur in a market led environment while applying their knowledge and skills to the work. Experiential learning has the ability to be an extremely positive or an extremely negative learning experience depending on how carefully it is managed. There has to be a genuine understanding from the employer's perspective that the student is still a student and not just 'cheap labour'. There has to be a desire on the student's part to get the most out of the experience. The educational managers must, if introducing experiential learning as part of a curriculum, be able to reasonably guarantee both of the above and must be in a position to manage the expectations of both. The focus must be on the educational benefit and the opportunity for the business to gain fresh input and expertise in a specific field.

Problem based learning as Barnett defines it is usually run in house and involves the setting of particular projects that students can use as a mechanism for learning (Barnett 1994). The projects attempt to reflect a degree of real world industry format and usually involve students working through a series of predefined stages. For the design sector problem based learning has been the staple learning strategy since the Bauhaus movement and so is, relatively speaking, not particularly new. It is interesting to follow the trend towards the use of PBL (Problem Based Learning) as a learning strategy in mainstream engineering and business education. It would seem that this trend is a natural deviation from the traditional 'Chalk and Talk' approaches adopted previously. There is intimation here also that PBL signals a move away from a bias only on knowledge and moves towards a skills based learning approach. Industry has become much more selective about the abilities of students to be multi-skilled and their soft skills in teamwork, self motivation and project management are now essential parts of their toolbox. It is no longer acceptable for graduates just to have technical expertise and vocational skills but also to have management, business and multidisciplinary ability.

David Orr in his book *Ecological literacy: Education and the transition to a postmodern world (Orr 1992)* is one of the few writers that has transcended the boundaries between educational theory and sustainable development. He differentiates quite succinctly between Education, Training and Learning and shows how our perceptions of each are moulded by the norms of the traditional educational system. He maintains that many of our issues with the miss-management of the environment have been directly caused by the educational elite who have a removed understanding of the workings of nature. He theorises that it is the education culture that causes the disjoint, it encourages an over reliance on high degrees of specialism and an inability of high end research to be really applied, effective and useful to society. Orr poses some very interesting opportunities for education in a postmodern world.

2.4 Traditional Design Education Models

Design in third level has traditionally been taught in a different manner to the traditional approaches within other subject areas such as Engineering, Business, Humanities and/or Science.

Design from the days of the Bauhaus at least was conceived as a discipline that was research focused from the start. It is often described as an 'Industrial Art '(Westphal 1991) .In the context of this research the three dimensional design disciplines of Industrial Design, Product Design, Architecture and Interior Architecture along with Furniture design are considered. Two dimensional design disciplines are also considered in the context of sustainability as they often have a strong role to play in the effective communication of SD solutions and in the expressing the complexities around sustainability.

Prior to the Bauhaus, design was taught in a formal sense but as an elite study with specialism and strict adherence to codes of practice and design styles. William Morris, John Ruskin and others began the move away from the notion of the artist, the architect or the craftsperson as separate disciplines (Pevsner 1936) and the integration of these became an important movement in the 'Arts and Crafts' movement of the late 19th and early 20th Century.

Craft skills and trade skills were of course taught from the middle ages in a guild model from master to apprentice however these skills and activities rarely involved the creative process as we understand it today. Through this model the craftsman, engineer or client unilaterally determined the nature of the work based on their personal expertise. The craftsman focused on the skill or the material availability, the engineer on technological requirements and the client on their personal taste. The result of this type of 'design' was often brilliantly successful but rarely was it fully rationalised or formalised. The philosophical intent was not implicit in

the design process and the evaluation seems to happen from a historical context rather than through the craftsperson's original thinking.

2.4.1 The Bauhaus

The Bauhaus set out from the start to challenge this notion. Most design historians agree that the Bauhaus had a significant impact on design and how design was taught (Droste 2002; Naylor 1985; Whitford 1984). Students in the early Bauhaus (Weimar, Germany, between 1919-1925) were encouraged in the process of design in a way that was total and detailed. They were exposed to experts from multiple fields of Technology, Art and Philosophy and were challenged to interpret both hand and machine made objects is more than just a technological or craft based manner. Mentors teachers and directors such as Gropius, Itten, Nagy, Albers, Kandinsky and Klee in the early days formulated radical new models for design education which not only did away with what preceded them but built a force in art, design, sculpture and architecture education that resonates to the current day. This Bauhaus model was developed further in the years leading up to world war two with a move to a new purpose–built building in Dessau. Through the directorship of Mayer and Van der Rohe the school grew into a new phase. Around 1928 Mayer developed the focus on designing for cheap mass production and moved away from the craft/materials based thinking of the earlier years (Westphal 1991).

This could be seen as one of the starting points for an unsustainable approach to design. Meyer was perceived as a left wing ideologist and so perhaps this fitted in with the concept of 'design for the masses' in a simplified sense.

More recently commentators like Huovio have looked back at the Bauhaus from a design history perspective and commented that the Bauhaus was in fact the foundation of what we understand to be modern design.

> An artist must be conscious of his social responsibility to the community. On the other hand the community has to accept the artist and support him.
> (Huovio, 2008).

And

> They were able to follow the changes in technology and society in a flexible manner. Homogeneous professional roles started to dissolve in practice, or at least to change radically. At the same time it seemed necessary for the student to take personal responsibility for his or her studies and the development of professional skills
> (Huovio 2008).

2.4.2 Contemporary Approaches to Design Education

In 1976 John Eggelston, in his book entitled *Development s in Design Education,* contextualised the Design Process using the diagram by Edward Arnold outlined in Figure 8,(Arnold and Eggelston 1971; Eggleston 1976).In the context of this research one could argue that very little needs to change in order to successfully educate sustainable designers. However, it is this very little piece that has been the key focus of much of this research. The traditional process remains similar to that outlined by Eggelston but it currently pre-supposes that the student has the ability to identify clearly the problem area and then follow the divergent and convergent thinking stages as backed up by Rhea and as described previously (Rhea 2003).

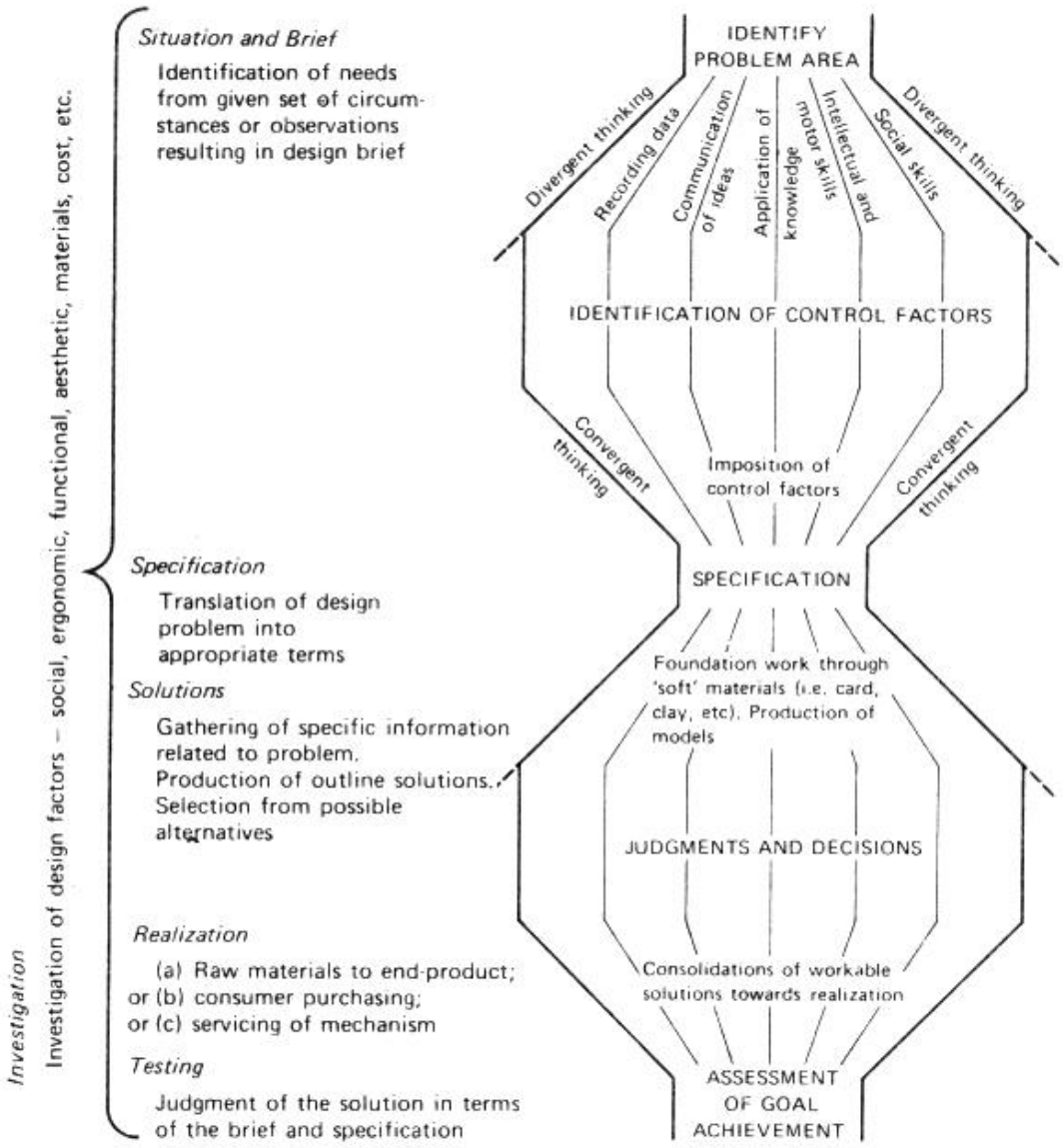


Figure 8: Design Process (From Design for Today) (Arnold and Eggelston 1971)

This is where some of the flaws in existing design education begin to appear with respect to sustainability. Alain Findeli describes this concept very well in his paper entitled *Rethinking Design Education for the 21st Century: Theoretical, Methodological, and Ethical Discussion (Findeli 2001).*

> The input "PROBLEM "and the output "ACTION" of the design process are considered as not being part of the design process. The "problem" is a given, and usually is considered as such in design practice and in the design studio of our schools. An "action" comes out of the process, ready to live a life of its own, in another realm. But, in reality, problem and action dwell in the same world, of which the designer also is part, not only as a professional, but also as a citizen.
> (Findeli 2001)

Sustainable development and the PROBLEMS it poses are clearly not ones that can easily be simplified in to tidy briefs for design students or for professionals; in this context it would also seem that the ACTIONS or designs would likewise not be singular in their proposals but multiple solutions depending on the shifting problems. The development of the students' literacy and context is a critical element in the mix and it is the development of this that is so often neglected.

More recently we have seen a fuzying of the boundaries in design with various schools and educational establishments seeing the value of design thinking and education in a wider context. Educational initiatives such as Kaospilots in Denmark (Kaospilots 2008) have pushed the boundaries of areas like Social Entrepreneurship, Leadership and the interface between Business and Society. Kaospilots is an avant-guard 'new business' and 'social entrepreneur' school that developed in the early 1990s in Denmark and grew campuses in Norway, Sweden and the Netherlands. They have succeeded in building the initiative with recognition from the traditional educational establishment in Denmark. Kaos Pilots in many ways have been more progressive in changing how we teach and learn creativity and social change than many mainstream design departments.

Wals and Jickling in their paper on *Sustainability in Education* make the following observations that drive home the point quite succinctly.

> Teaching about sustainability requires the transformation of mental models. Teaching about sustainability presupposes that those who teach consider themselves learners as well and that students and other concerned groups of interest are considered as sources of knowledge and feelings too. Teaching about sustainability includes deep debate about normative, ethical and spiritual convictions and directly relates to questions about the destination of humankind and human responsibility. Sustainability in educating demands serious didactical re-orientation.
> (Wals 2002)

Also Garner makes the following observations:

> Designing and design education have always displayed complexity but clearly both are more complex today than even a few decades ago. Students need to know how to access and utilise many types of information, they need to engage in multidisciplinary team working, resolve conflict, generate innovation and manage information, people and systems
> (Garner 2005)

2.4.3 Sustainable Literacy

As discussed previously, one of the key observations that the research has noted is that students and professionals alike often do not have the ability or the literacy to identify the core problem. Literacy or more precisely the development of the student's sustainability literacy is a critical output of this research.

> Sustainability literacy can be defined as an endeavour to develop knowledge, values and skills that enable students to participate in decisions about the way we do things individually and collectively, locally and globally that will improve the quality of life now without damaging the planet for the future. Sustainable literacy encompasses the following:
> - An appreciation of the importance of environmental, social, political and economic contexts of their discipline.
> - A broad and balanced foundation knowledge of sustainable development, its key principles and the main debate within them, including its contested and expanding boundaries.
> - Problem solving skills in a non-reductionist manner for highly complex real life problems.
> - Ability to think creatively and holistically and to make critical judgements.
> - Ability to develop high level of self-reflection (both personal and professional).
> - Ability to identify, understand, evaluate and adopt values conducive to sustainability.
> - Ability to bridge the gap between theory and practice, in Sustainable Development, only transformational action counts.
> - Ability to participate creatively in interdisciplinary teams.
> - Ability to initiate and manage change.
>
> (Sirat and Panfian 2007)

Literacy can have multiple interpretations but for the purposes of this research the following were taken as benchmarks.

> 'Literacy' is the ability to identify, understand, interpret, create, communicate, compute and use printed and written materials associated with varying contexts. Literacy involves a continuum of learning to enable an individual to achieve his or her goals, to develop his or her knowledge and potential, and to participate fully in the wider society.
> (UNESCO 2004)

> Sustainability literacy is about learning how human actions affect the immediate and long-term future of the economy and ecology of our communities. In short, how we must learn to live and work on a planet whose resources are finite (HEA 2006)

The latter quote is from the 2006 UK Higher Education Academy report entitled *Sustainable Development in Higher Education, Current practice and future developments.* It makes a series of observations based on research which shows how many sectors in UK higher education have significantly built on their curricula to include the sustainable literacy that is desirable.

This suggestion that literacy is important is perhaps significant since the core problem within any sustainable design challenge is usually multifaceted. The Prior Knowledge study shows in this case how little both students and professionals claim to be familiar with some of the key issues around the sustainable development agenda (see conclusions in 4.2). The assumption needs to be made that in order to benefit significantly from any applied work in sustainable design the learner needs to first be given the opportunity to develop their sustainable literacy. The two do not necessarily need to happen chronologically however a degree of basic literacy would be needed to start any applied work. It is possible to develop the literacy through the course work and this is perhaps more effective as a metric for the students development. It can be challenging to use didactic forms of literacy development as their effectiveness is less clear. Lecture based teaching and learning methods would seem to be less effective as a means of developing literacy as the retention levels of the students is largely dependent on the assessment method that they have to undergo (Barnett 1994).

Jerome Bruner introduced the notion of ‘Instructional Scaffolding’ in the late 1950s (Bruner 1960) by this he was describing the use of certain tools to assist language acquisition in children. While the research did not explore this concept explicitly through the case studies the thinking that one can provide a temporary scaffolding to assist the adult learner in developing their sustainable literacy is an interesting parallel.

The suggestion that we give the design student a learning aid by providing stories, templates and case studies of contemporary sustainable design has direct parallels to the approach taken. Bruner was referring to the use of exemplar studies in order to inform curriculum development. In addition instructional scaffolding has been described as similar to telling bed time stories to young children - it gives the mind a temporary scaffold for developing language and vocabulary.

It is clear from the literature that the development of specialist literacy is a critical building block for the learning process. The strategies for the development of this sustainable literacy in learners needs to be varied and engaging to ensure that different types of learners (as in Figure 33: Felder-Silverman model of learning dimensions) can retain and continue to adjust their literacy.

2.4.4 Design Thinking

In his book entitled *How Designers Think* Bryan Lawson describes very convincingly the complex levels of thought that designers use in order to come to design solutions. (Lawson 1990) These patterns are not of course exclusive to designers however the particular combinations of thought are perhaps what allow the good designer to deal with both rational, logical progression on the one hand and on the other hand lateral and seemingly disconnected patterns on the other to come to various solutions to any given set of issues. Lawson describes the Gestalt school of psychology with work from Wertheimer (1959) – he maintains that problem solving involves grasping the structural relationship of a situation and reorganising it until a way to the solution is found. This describes very well one of the processes that design students are asked to develop in terms of addressing complex challenges. He goes on to describe the use of analogy as a means of shifting the design thinking approach. Often when developing the teaching methods in the various elements of the course it was appropriate to address complex issues around sustainable design as analogies rather than just raw data. In addition the use of analogy and re-organisation as tools for addressing problems allow multiple discipline groups to communicate on a common level. This common literacy is crucial in developing the ideas and in determining the effectiveness of any given solution.

2.5 *Interdisciplinary, Multidisciplinary or Transdisciplinary?*

It has become increasingly apparent throughout the research that the education of product designers and engineers on its own will be insufficient in terms of dealing with the challenges of sustainable development. For these professionals to be effective in applying their specialism they need to have the ability to communicate and work effectively with many disciplines. With this in mind it has been an important element of the research to look at models of education that encourage this multi or interdisciplinary approach.

> Multidisciplinary is present when researchers work in parallel or sequentially from disciplinary-specific bases to address common problems." Interdisciplinary consists of "researchers work[ing] jointly but still from disciplinary-specific basis to address a common problem," whereas transdisciplinary comprises "researchers working jointly using [a] shared conceptual framework" that draws together concepts, theories, and approaches from the parent disciplines (Rosenfield 2005)

Gertjan de Werk and Karel Mulder (de Werk and Mulder 2004) from the Technical University (TU) in Delft have done some interesting and applicable work in the area of multi/transdisciplinary education with the development of a special graduation certificate for engineers who have a wish to deal with sustainable development in their final degrees. They argue that it is critical for engineers in this case to be faced with the challenge of communicating their sustainable design thinking to other professionals but equally they see a benefit in jointly educating diverse disciplines so as to develop the broad world view alongside of the specialist technical skills. It would seem that as previously mentioned TU Delft has been at the forefront of developing SD education. The University has developed as a central focus the need for SD in all aspects of their curricula. The researcher had the opportunity to work directly with de Werk and Mulder over the period of the research through contact made from the EESD conferences. These resulted in a series of papers on the topic of student involvement in the educational process (de Werk *et al.* 2006) and also on connecting 'silos' in sustainable design education (de Eyto and de Werk 2008). In addition, the research was able to observe the Bootweek as a case study (as described outlined in 0).

It was observed that the case studies were mainly multidisciplinary in nature with respect to the MDP undergraduate work and were more Interdisciplinary in the context of the SME and SDI Case studies (see 4.7 and 5.5).

The undergraduate students (see 4.4), whether working with each other, marketing students and or students from other institutes, did mix and learn from each other. The nature of the

collaboration was interdisciplinary in type but often there was a reversion to specific disciplinary roles working in parallel once the initial forming of the groups had been achieved.

The SDI and SME case studies, (see 5.5 and 4.7) on the other hand, were much more interdisciplinary in nature throughout. The different professional disciplines allowed for mutual respect and collaboration to show through. There was an acknowledgement of a common set of problems and clearly each specialist brought their specific skills to the table.

It is perhaps a little pedantic to differentiate between the two but the subtlety is an interesting one in the context of observing how the different learning strategies affect the way that students collaborate on sustainable design work. For the purposes of this research the word *multidisciplinary* was used as it animates more honestly the results of the research. From an aspirational perspective one would prefer to see an interdisciplinary and even a transdisciplinary approach to SD education develop. This is perhaps within the scope of further research.

2.6 Educational Initiatives and Networks

There are a number of educational initiatives and networks that were valuable as a means of case study and peer benchmarking for the research. The key initiatives are outlined below and these involved participation as both an observer and a contributor throughout the research

2.6.1 DEEDS (Design Education and Sustainability)

Alastair Fuad- Luke has been a key mover in the application of much of his own and others' thinking through his directorship of the DEEDS project (DEEDS 2007). This European-funded project included work from around Europe into sustainable design education. It provided a series of key principles know as the DEEDS core principles upon which to build sustainable design education and professional practice. These key principles act as a check list for designers and students against the design work that they are carrying out. The DEEDS project also brought together individual design educators and design professionals from around Europe to contribute to the dissemination process through *Podscapes,* a type of short format presentation of tools, strategies or practical teaching and learning resources. These *Podscapes* were intended as open source sharing of ideas between those interested in sustainable design and education. The DEEDS project highlighted the need for a cross disciplinary approach to SD education however it was one of the few initiatives that had a pan European brief to focus on the Industrial design, Architecture and more creative ends of the design field. Some excellent commentary on sustainable design education is available in

the form of short video pieces through the DEEDS website. The overall approach of DEEDS was innovative in its presentation as it provides both specific case studies and also broad philosophical principles and tools that assist the designer and the educator alike. The presentation of the work in this case has the potential to have a greater impact on the education and professional design field as it is less formal and traditional in its approach when compared to conferences, published papers and peer reviewed journals. The DEEDS core principles greatly informed the development of the SDI course as outlined later and Fuad-Luke was invited in as a facilitator during the development phase of the syllabus. The pragmatic approach that the DEEDS project espouses is supported by the findings of the research here and it is this mix of the applied pragmatic approach to sustainable design along with a broader ideologically based understanding of the issues that develops a holistic designer or indeed design student.

2.6.2 RAE VP Scheme (Royal Academy of Engineering, Visiting Professor)

The Royal Academy of Engineering (RAE) developed a broad ranging initiative which started in 1998 and continues to have significant impact on the engineering design courses and universities in the UK that participate.(RAE 2008) The Academy sponsored a total of twenty-six UK universities to develop teaching material through the collaboration with appointed VPs or visiting professors. In this case the VPs were individuals who in a professional capacity demonstrated high level expertise in implementing sustainable development practice within their industry sector. The collaboration with academics and educators allowed the RAE to facilitate the development of a series of case studies and learning tools for teaching the designers and engineers of the future. A series of supporting seminars along with the day work of the VPs allowed the universities to share their findings and to develop a best practice model for weaving sustainable development principles throughout the engineering courses. Bournemouth University's DEC school continues to be one of the twenty-six participants and the development of the SPD web based learning tool provides an example of some of the work undertaken by the VP scheme (DEC 2004). This website formed one of the early evaluation studies with undergraduates at IT Carlow (as outlined in 4.6).

Perhaps it is the scale and depth of the RAE initiative that was most impacting. It illustrates what a professional body can achieve in terms of influencing universities and institutes Also it shows that a strong professional body can lead a set of disciplines towards taking a more ideological and pragmatic stand on issues that affect how we work and live.

2.6.3 EESD (Engineering Education for Sustainable Development)

The EESD was first formed as a conference for European universities that were keen to explore together ways of implementing sustainable development within their engineering and design curricula. The first of the conferences was held in TU Delft in 2002 and this was followed in 2004, 2006 and 2008 with other conferences in the network being organised around Europe. Many of the key universities and institutes not just from Europe but also from the rest of the world have published and contributed to this sharing of knowledge. Aside from the conferences themselves the participant universities have developed a series of lobbying, policy development and other networking initiatives to aid in the spread of a best practice in sustainable development in educational curricula.

The ongoing research from this study was published at two of the later conferences in an effort to seek peer review and to benchmark the work against other similar initiatives across the world. The most valuable part of these types of conferences is in the personal contacts made. It has been possible to have detailed discussions and sharing of educational approaches with educators from TU Delft, UPC in Barcelona, Chalmers University in Sweden, Monterey Tech. in the US and Mexico and other highly respected universities. In many cases the innovative approaches are taken by smaller institutes like our own here at IT Carlow and Bournemouth University. The range of initiatives within the EESD program reflects the opportunity for all levels of both academia and business to build their capacity in teaching sustainable design and development.

As the Barcelona EESD 2004 declaration established, students also need to:

- Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts.
- Understand the contribution of their work in different cultural, social and political contexts and take those differences into account.
- Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management.
- Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down in to disconnected parts.
- Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more sustainable development.
- Apply professional knowledge according to deontological principles and universal values and ethics.
- Listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures.

(EESD 2004)

2.7 Selected Reports and Studies on Sustainability in Education

In October of 2000 the Joint Research Centre of the European Commission published the findings of a study of eco-design strategies within select countries in the EU (Tukker *et al.* 2000) In the study they classified countries in three distinct clusters which determined the level of support available to SMEs (Small and Medium Enterprises). Within the clusters, Ireland which is the focus of the research to date falls in to the lowest category in terms of support for SMEs with respect to eco design. The report states that there is limited support for eco design and that it is still poorly institutionalised in this respect. The research sought to broadly assess the developments since 2000 with respect to this sector and the findings and methods used are outlined later in the report.

Broadly speaking the reports overall conclusions and analysis determined that certain countries such as the Netherlands, Sweden, Denmark and Austria have well developed traditions of sustainable design thinking which are widely accepted as useful as a tool for competitive advantage for SMEs. This is reflected in the wider market perception that key international brands from these countries, Philips and Volvo for example, have higher environmental and social criteria than their competitors. As suppliers to these key multinationals often SMEs are forced by market pressure, legislative requirement and procurement rules to comply with the higher standards also.

Countries such as the UK, France, according to the report fall in to the middle category of having pockets of support based on Government or local organisations. The report recommends the combination of formal and informal networks to promote and disseminate knowledge and to work in partnership with SMEs to improve their eco design capabilities.

The most comprehensive study of present models of sustainable design education (at least in Europe) is presented in the UK Design Councils Scoping Report from 2005 (Richardson *et al.* 2005) It undertook a broad brush assessment of existing Sustainable Design Education in the UK and compared it to what they term Mainstream Design Education. Some of their conclusions are cited below:

> Our research showed that many of the differences between Mainstream Product Design Education (MPDE) and Sustainable Product Design Education (SPDE) mirror the differences between Mainstream and Sustainable Product Designers. In general, MPDE still focuses primarily on equipping students for positions within mainstream product design which sees the mainstream marketplace as providing the main employment opportunities.
> (Richardson *et al.* 2005)

Further information on best practice when working with SMEs is compiled in a publication by (Hillary *et al.*2000) with some excellent chapters on various topics surrounding the introduction of sustainable design and manufacture and also dealing with the attitudes of SMEs towards the environment and sustainability.

The work of the EESD Observatory has given one example of a benchmarking system for European institutes and Universities with regard to sustainability education (Motrel 2006). In this case they have applied a generic set of questions and metrics to both individual lecturers and managers within a broad range of participating universities and European institutes. Data is collected through a survey distributed to 400 European universities of technology and answered (in 2008) by 56.The ranking is based on five criteria, each with the weight 0, 2:

1. The university's official policy on EESD for research, education and in-house activities
2. Education - courses on SD at undergraduate level
3. Education - postgraduate program on SD
4. Education - embedding of SD in the curricula
5. In-house Environmental Management System

In 2008 this ranking (which is based on self-reporting) was supplemented by a Search engine ranking (counting sustainable words on the university's website) and a Peer ranking.

The EESD observatory only focuses on sustainability education within engineering faculties. In the case of IT Carlow, which does get a mention in the report, the design courses are set within the School of Business and Humanities and so often these nuances cause categorisation difficulties. Bournemouth University, unfortunately in both the 2006 and 2008 reports, does not receive a mention; it is possible that they were missed in the survey as many of the participants are linked through contact through the EESD conferences which occur bi-annually. The report does show how difficult it can be to provide balanced case examples of SD education. European universities and institutes compete in a very disjointed manner for recognition and visibility and while some universities clearly lead the way in terms of quantity of initiatives, many others fall foul of a lack of marketing in terms of SD.

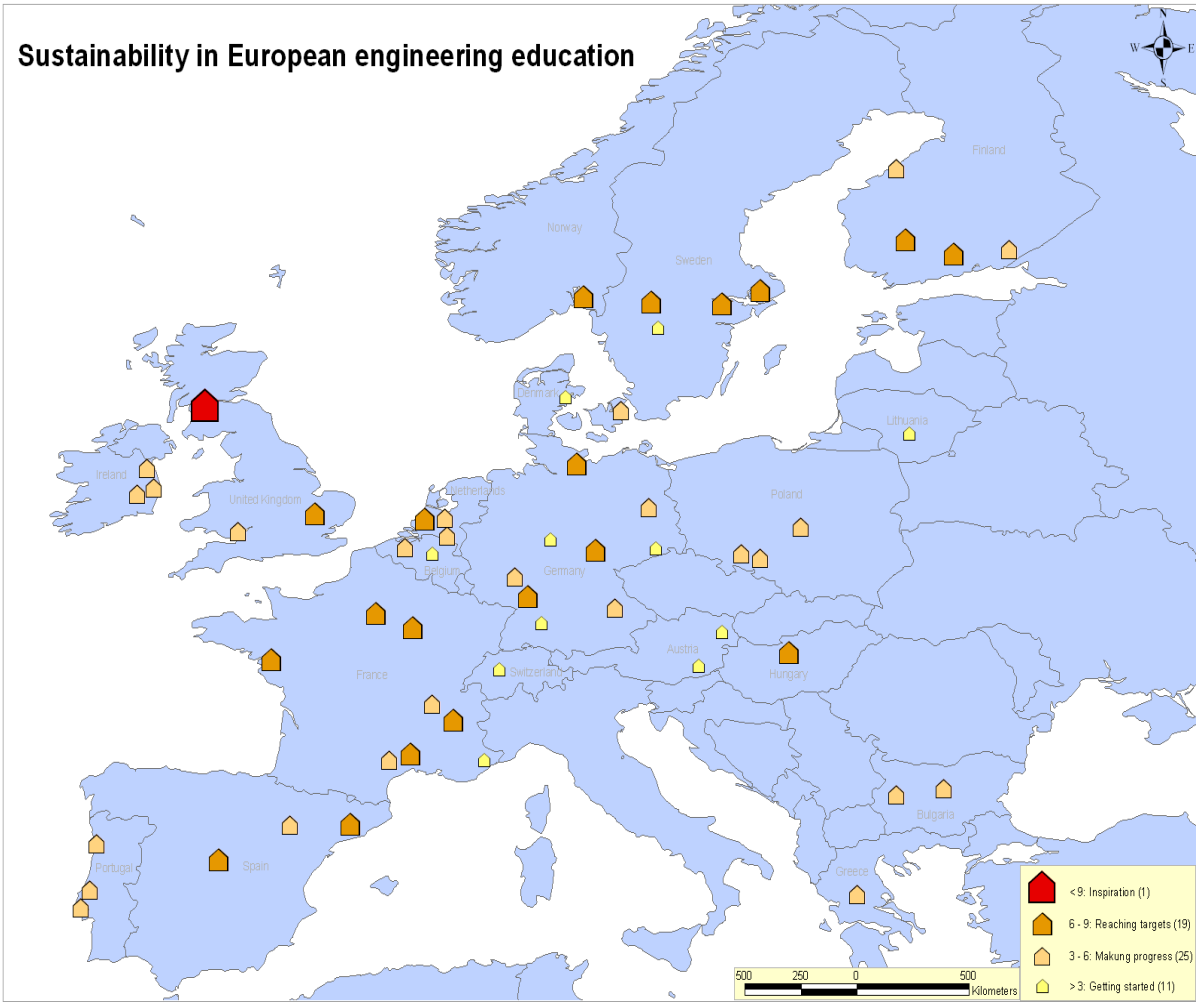


Figure 9: EESD Observatory 2008 report overview (Motrel 2006)

Other Institutes have been less co-ordinated about their approach at an institutional level – our own at IT Carlow being one; however, this does not negate the efforts that have been made at a course level. The research findings suggest that often the most innovative approaches to teaching and learning of sustainable design are done by specific 'champions' in niche areas. Institutional commitment helps but is not necessarily a pre-requisite. In fact some courses and individual lecturers have indicated that where institutional sustainability policies are in place they can act as a restrictor to innovative teaching methods (de Werk 2008).

There is some critical longer term research being done in Wales on the subject of embedding sustainable design in industry by Simon O'Rafferty and Dr Frank O'Connor of the (EDC) Eco Design Centre.(O'Rafferty 2008). They had a close liaison with both the ReForm seminars and the SDI program as part of this research. This work shows how carefully targeted initiatives can develop sustainable design capacity within SMEs. In the case of the

EDC the direct support they receive from the Welsh assembly government and the specialist team of expertise that they have built up steadily over time has hugely strengthened their effectiveness. EDC have also seen the need to develop the educational curricula and have done some excellent work with the welsh universities in raising awareness of sustainable design.

2.8 Networks

There are a plethora of networks and peer groups that exist around the area of sustainable design. At the commencement of the research these were fewer and more difficult to become involved with, but in the later years as sustainable and eco-design have increased in importance there has been a marked increase in the number and quality of the discussions and networking opportunities that exist.

The networks that were used and contributed to as part of the research here include:

- The o2 Global network (Van Hattum *et al.* 2009)
- The o2 Ireland Network (de Eyto and Mc Mahon 2009)
- The Osiris Network, TU Delft (Rademaker 2009)
- SDN (Sustainable Design Network) run through Loughborough University, UK(Lofthouse 2008)
- Cradle 2 Cradle community network (MBDC 2009)
- Sustainable Everyday Project run through Milan Polytechnic and Ezio Manzini (Manzini *et al.* 2007)
- DEEDs Project (DEEDS 2007)
- Linked In.com (professional social networking facility) (Linkedin 2008)
- Design Ethics Group , run from NCAD by Derek Mc Garry

2.9 Critical Appraisal of Literature and Context

As can be seen from the wide variety of specialist literature there has been a development in specialisation around sustainable design since the 1970. Furthermore there has been a trend towards developing education towards a more self directed and less prescribed syllabus in many courses.

Papanek and Fuller (Fuller and Snyder 1969; Papanek 1971) clearly published their thinking at a time when it was against the mainstream trends. Their foresight and wisdom in predicting many of the challenges that we currently face is remarkable and certainly the passage of time has allowed their observations mature. The challenge that these commentators and the more recent writers (Chapman and Gant 2007; Fuad Luke 2009; Mc Donnagh and Braungart 2002) continue to face is in influencing change at an educational level. There is little doubt that their thinking has been hugely influential in changing the syllabi of specific courses. Despite this in many cases there is reluctance towards institutional change. The EESD observatory report (Motrel 2006) and the UK Design Council Scoping Report (Richardson et al. 2005) provide us with some insight in to the slow take up in traditional engineering and design education of sustainable design.

2.9.1 Educational Policy

At a local level within Ireland there has been very little movement on introducing change to the curricula. As can be seen in 1.5.4 the current institutions that teach industrial design and product design have changed little in their approach to sustainability. Aside from the initiatives at IT Carlow and UL the other courses have dealt with it at a token level rather than at syllabus level. In the wider context Engineering, Marketing & Business courses have shown little inclination to radically alter their syllabi to reflect the changing world environmental and social needs. Architecture and social sciences on the other hand have shown that they are dealing with the changes, a small number of undergraduate courses and masters programmes have developed which show, at least in course name, that sustainability is central to their focus.

Comhar the Sustainable Development Council (one of the policy development bodies of the state) is only addressing the shortfall in education in the last two years (2008/09). Their initial response (Casserly 2009) has been broad and non specific and would seem to focus on incremental change in a few sectors and broad vision statements for others. There are few direct recommendations or policy directions that give the commitment of HETAC (Higher Education and Training Awards Council) or the HEA (Higher Education Authority) to their vision. This would suggest that despite the broad representation on their council the influence so far on the educational sector may be limited. The provision of third level education in Ireland as with many other countries is heavily politically influenced. Policy changes that effect funding and

radical departures from the mainstream are uncommon. Multiple bodies have responsibility at a state level for management and development of the educational agenda so it can be understood that *Comhar* have a difficult role in influencing change towards a sustainable development inclusion.

What is clear from the literature review is that despite a dearth of case studies and academic papers (as in 2.5) on the introduction of sustainable development and design to third level curricula there is still a blockage within many universities and institutes preventing them from initiating change. Similarly at a CPD level there have been a number of courses which look at specific issues around Eco Design in Architecture and Energy Efficiency (RIAI 2009), however there has been no visible attempt to educate professionals holistically and in a multidisciplinary fashion towards sustainability. In fact many of the professional bodies in the state do not have formalised CPD programmes and therefore have a real challenge in delivering any continuing education to their members.

2.9.2 Institutional Change

Sustainable development has clearly been embraced a number of levels by a range of key universities and institutes across Europe. The work of the EESD observatory has been one of the few comprehensive studies that attempts to rate institutions on their performance (Motrel 2006) Clearly in the most recent 2008 report (Motrel 2008) from the EESD Observatory the University of Strathclyde, Scotland comes out on top. Larger Players such as TU Delft, Netherlands, Chalmers University, Sweden and UPC, Spain all consistently score highly on this ranking. They have been at the forefront of collaborative change at a European level, they clearly provide institutional leadership and facilitate the involvement of many smaller institutions through organising conferences, lobbying and funding at a strategic level. This focus on sustainable development is critical at an institutional level and as an overarching context for sustainable design education. The institutions mentioned above show their effectiveness through developing the collaboration between the multiple departments and disciplines.

The RAE scheme covered in 2.6.2 provides a more focused pragmatic example of how institutional change can be facilitated through a national level strategy. It clearly had influence on the engineering universities that it had involvement with over the period. It shows clear leadership by a professional body and exemplifies the type of intervention that a strong professional body can achieve.

Theme	Key theme/approach	Supporting theories from literature	Application within research
Educational themes			
Learning	Active Passive Self directed Collaborative Group Observation and Reflection Active Experimentation Experiential Learning Studio based learning Multi/Interdisciplinary Problem based learning Peer to Peer learning Networking	Experiential learning - (Kolb 1984) Group learning - (Tuckman 1965) Experiential learning - (Barnett 1994) and (Kolb 1984) Design process - (Arnold and Eggelston 1971) Studio learning - (Roberts 2004) Learning process - (Bloom 1956) Problem Based Learning - (Papanek 1971; Roberts 2004) Learning Dimensions - (Felder and Silverman 1988) Multidisciplinary - (de Werk and Mulder 2004) and (Rosenfield 2005)	Studio Undergrad Projects SDI Winnovate Reform seminars
Teaching	Facilitation Co-Learning Didactic Expert Specialist Student Directed Mentoring	Andragogy v Pedagogy - Knowles (1973) Student directed - de Werk (2008) Co-learning - Findelli (2001) Core principles - DEEDS (2009) Education for Change- Sterling (2001)	Studio Undergrad Projects SDI Winnovate Course development
Literacy	Sustainable Literacy Design Literacy Business	Literacy - Barnett (1994) Design process - Arnold (1971) Eco-Literacy- Orr (1992)	ReForm seminars Debates, Studio projects, SDI Program, Interinstitutional Initiatives.
Application	The Design Process Design Practice Sustainable Design Practice	Design thought/design process - Lawson (2006) Arnold	Live projects, SDI program, Reform Seminar. Graduate Experiences.
Multidisciplinary	Community of Practice Interdisciplinary, Multidisciplinary or Transdisciplinary	Interdisciplinary Education - (de Werk and Mulder 2004) Change - (Mao 2004) Communities of Practice - (Wenger 1999)	SDI, Undergraduate MDP Projects, ReForm Seminars BootWeek
Review	Peer Assessment Critique Self evaluation Mentoring	Kaos Pilots Education - (Kaospilots 2008) Grade Inflation - (Guilfoyle 2008; O'Grady and Guilfoyle 2007) PBL-(Roberts 2004)	Studio Undergrad Projects SDI Winnovate
Sustainable design themes			
	Materials Flows	Cradle to Cradle - (Mc Donnagh and Braungart 2002) LCA - (PRé 2009) Materials selection - (Granta 2009)	Studio Undergrad Projects Multidisciplinary Projects Interinstitutional case studies SDI Winnovate ReForm seminars
	Sustainable Design approaches	Eco- Design - (Fuad-Luke 2002),(Lewis *et al.* 2001), (Papanek 1971) Sustainable Design - (Tischner and Charter 2001), (Bhamra 2007),(Chapman and Gant 2007), (Walker 2006)	
	Ethics	Socially Sustainable Design - (Whitley 1994)	
	Lateral thinking	In The Bubble - (Thackara 2005) Design Thinking - (Papanek 1971),(Lawson 2006)	
	Creativity	Re-thinking creativity - (Findeli 2001) Developing creative thinking - (Gaytán 2008)	

Table 2: Key themes from Literature Review that Inform the Research and the Thesis

2.10 Gaps in the literature and Context

The literature reviewed above gives an overview of best practices, strategies and philosophies around sustainable design education at the time of writing. There are clear gaps in the literature that have formed the basis for this research.

The underlying theory applied here is that Multidisciplinary education is essential in order to effectively educate both students and professional with respect to sustainable design. This multidisiciplinarity has clearly not been addressed sufficiently within the sustainable design education field before. There have been various attempts through the networks (described in 2.8) and conferences (Outlined in 2.6) to bring together parallel disciplines in the spirit of discussion and sharing of ideas but no visible attempts at formally educating towards SD in a multidisciplinary way. Furthermore there have been no long term studies of how student designers and professionals can benefit from learning together about sustainable design. The observation of the progression from undergraduate student to professional has also been lacking in this field of study.

This combination of studying the practical application of sustainable design thinking with the theoretical understanding is an essential gap that gives opportunity to further research. A number of authors (Ali Khan 1995; Bhamra and Dewberry 2007; Sterling 2001) have highlighted to these opportunities previously, this research aims to provide tangible case studies and action based research in to the opportunities at both an undergraduate and a professional level.

In conclusion the objectives for the research, as derived from the gaps outlined through the literature review, were as follows:

- To design and implement a series of educational strategies that embody the principles of multidisciplinary sustainable design education
- To draw on the large body of current knowledge in sustainable development and design and to animate this with the case study groups
- To observe and contextualise the findings of a longer term study of undergraduates and design professionals to evaluate how effective these learning strategies were.
- To highlight opportunities for further research and follow on initiatives for SD education with undergraduates and professionals.

3 Methodology

3.1 Introduction

The research outlined through this thesis was specifically developed with sustainable design education as the core focus. Educational research in this context requires a series of approaches from a research methodology perspective. This chapter will outline the methodology that was used in the development of the research and the thesis. The methodology that was developed took into account the complexity of the task in terms of answering the primary research question.

How can third level effectively educate students, SMEs and professionals in sustainable design so as to be able to apply their knowledge, skills and competencies to design and industry practice in an effective manner within a complex and rapidly changing world paradigm?

It needed to be both clear and flexible in order to account for the variables that occurred over the duration of the research. The variables included a number of new course developments at IT Carlow that were in process at the commencement of the research and the opportunity to engage SMEs through the Winnovate program and through the ongoing development of Design CORE (an applied research center in industrial design at IT Carlow).The researcher was and is directly involved as a lecturer in these courses and had the opportunity to initiate and collaborate at all stages. Hence the use of action research was deemed one of the most appropriate methodologies.

The overarching methodology was largely lead action research approach (as outlined in 3.2) and informed by the case study approach (as outlined in 3.4).The action research and case study approaches informed the other methodologies and allowed for the establishment of a base line from which to develop each initiative in the latter part of the process. The case studies observed included the following:

- Winnovate Initiative at IT Carlow
- TU Delfts' Bootweek
- Bournemouth Universities web-based SPD e-learning tool
- ReForm Seminars
- Series of Undergraduate case studies and multi-disciplinary projects at IT Carlow
- Other institute workshops (at NCAD and IT Sligo)

The methodology was mainly qualitative in nature focusing on the interpretation of case studies that allow for the exploration of existing and new methods for sustainable design education.

The intent was to describe through the new methods and strategies the essential elements of andragogy and learning that take place in a well designed curriculum. Some case studies, such as the seminar model, were not strictly speaking curriculum based however these were explored as complementary vehicles for building on the learning of both students and professionals. They also contributed to the multidisciplinary aspect of the research in areas that proved difficult from an institutional collaboration perspective.

Qualitative research does not necessarily require the inclusion of large numbers of sample groups and so this was chosen as the more effective method over a quantitative study. The numbers in the research were not the primary focus but it was important to include a broad spectrum of learners and where possible to develop the methods over a period of time in an action-reflection cyclical manner (as described in Figure 10).

The methodology was interpretive in nature; it sought to interpret the qualitative outcomes of the preliminary case studies and to interpret the current best practice from a sample of local and European initiatives. This interpretation informs the new methods that were developed as part of the contribution to knowledge. The proposal of a new model for SD Education as outlined in 7 is a form of ‘theory construction’ as described by Mc Niff (Mc Niff 2006).

The interpretations are formulated within the thesis and further in the series of conference papers, conference presentations and peer reviewed journals as one means of peer review. This peer review was undertaken throughout the time period so as to critique and inform the ongoing research. Further levels of review were sought through direct peers; the supervisory team, work colleagues, collaborating researchers from other fields and the undergraduate and professional learners who were part of the research (The peer review method is described further in 3.6).

To summarize the key research methods used were as follows:

- Action research
- Prior knowledge survey
- Case study research
- Interview

- Peer Review
- Curriculum co-design
- Feedback survey

The methodology that was employed here was in the main developed over the duration of the research period. It was not possible to anticipate fully where the opportunities for curriculum development were going to arise at the outset of the research and so methods such as 'Curriculum co-design' (3.5) and the use of interviews (3.7) only became a possibility as the work progressed.

It was anticipated at outset that there would be possibilities within the day to day work of the undergraduate courses at IT Carlow to use the case study (3.4) and action research (3.2) models and also it was desirable from the start to assess the prior knowledge of any participants in the research.

As a practitioner, the research and new theory had to be of an applied nature to be of value. This is not to say that non applied theory is invalid, but more that the methodology used here was one of action and collaboration, of participative democracy and of a desire to explore the possibilities for a genuine and holistic move towards integrating sustainable development in design education.

3.2 Action Research

The overall tenet of the research was one of action research. This has been the focus of much debate and research in its own right as a methodology for research however it would seem to be the most appropriate description for the type of research undertaken here.

> Action research is a form of enquiry that enables practitioners everywhere to investigate and evaluate their work
> (Mc Niff 2006)

The intent from the outset of the research was for the researcher to be an integral part of the process and to explore in a collaborative way the possibilities for sustainable design education. Other research methods such as those adopted by many in social science where the researcher stands 'outside' the situation ;sometimes referred to as 'Spectator Research' (Mc Niff 2006), allow perhaps for a more clinical evaluation of the learning and learning outcomes. This however would suggest a more defined use of the sample group, the subject matter and the expected outcome. In this case it was clear that an 'insider' approach was

necessary as the nature of design education is one of action and reflection rather than hypothesis and proof.

The action research approach was chosen as the researcher was directly involved on a day to day basis as a lecturer with many of the undergraduate case study groups. This meant that it was appropriate to evaluate on an ongoing basis the progress of the case studies and to reflect on their efficacy in terms of the development of the new methods (see Figure 10). There is the possibility of a conflicting role here between researcher and lecturer however the methodology used in the research ensured a separation of these roles when analysing the outcomes.

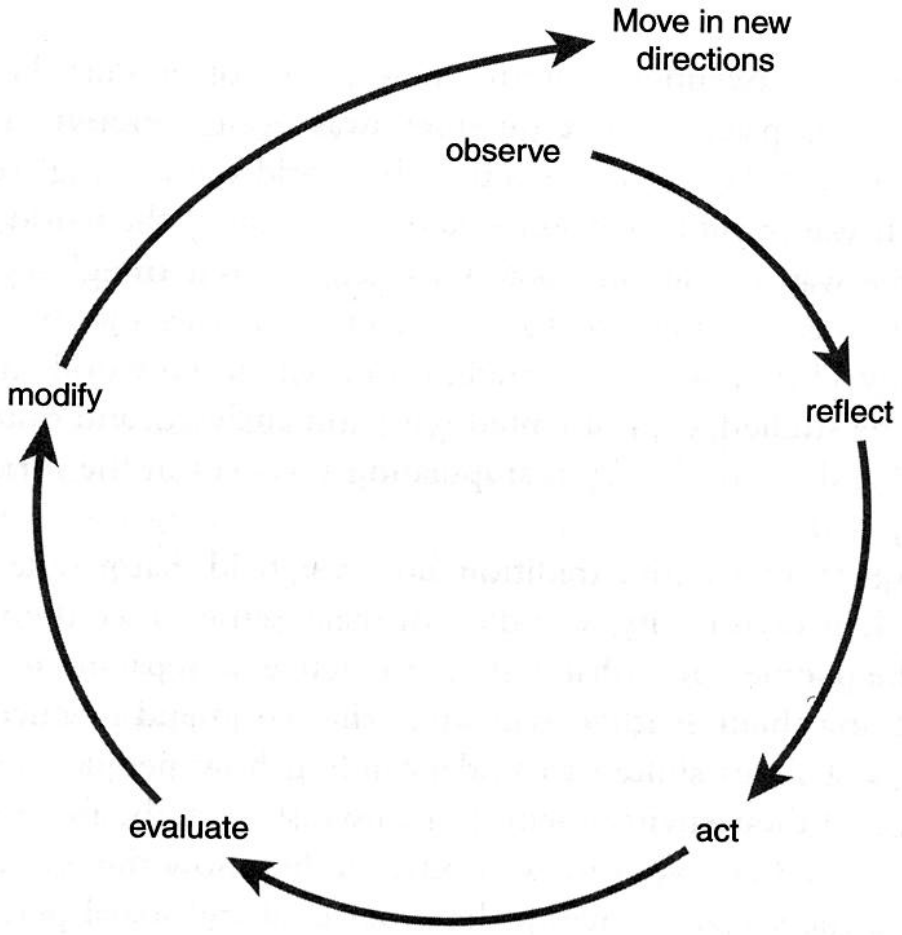


Figure 10 : Action-Reflection Cycle, (McNiff et Al 2003)

In addition it was intended to use the notion of 'critical friends' (Mc Niff 2006), i.e. the lecturing team of nine in the design department at IT Carlow, as peers to critique the ideas and the methods that were developed. There were some limitations here as the group were not formalized by the researcher at the start of the process and while regular feedback and

discussion was sought and given, this feedback was not recorded and so an opportunity for validation of this element of the research was lost. Additional methods for peer review were chosen as a means to test the strategies and put them in to the public domain, these are outlined further in 3.6.

The opportunities for SME and professional development were not immediately apparent at commencement of the research, as they arose it was clear that an action research approach to the development of the coursework and syllabus development would be the most appropriate. The researcher acknowledged that many of the professionals that would take on either of these programs would be direct peers with a detailed knowledge of industry. The collaborative approach in this case allows for an exploration of the appropriate methods for sustainable design education with the learner and in fact the action research approach allows for the researcher to also be a learner.

The Action research approach does have some limitations in the context of generating quantitative data for the purposes of validating the strategy. Since the case studies would be of relatively small sample groups there are some issues around scaling the new learning strategies for use in a wider context. The teaching and learning strategies that were developed through the research have clear value to design education and to CPD. A more detailed quantitative study would need to be used to prove the approaches in other disciplines.
The researcher took the following roles in the case studies outlined so as to facilitate but also observe the case studies.

- In the Undergraduate Case Studies (4.4.3 & 5.2.3) the researcher acted as facilitator and mentor for most of the projects while also observing the directions that the projects took. In some situations it was necessary to encourage direction and re-focusing of projects to ensure a more holistic outcome.
- In the Student Directed Case Studies (4.4.2 & 4.4.4) the students took the lead role in their own work with the researcher acting as mentor only. Of course there was still a requirement on the researcher to grade the work on a continuous assessment bases with colleagues.
- While working on the SME Workshops and the ReForm Seminars (4.7& 5.4) the researcher took the role of both Lecturer and Facilitator. These required a more traditional teaching approach but were complimented by the researcher also acting in a workshop or seminar organiser capacity.

- The researcher acted in an observational capacity only on the Bootweek Module with TU Delft (5.3).This afforded the possibility to fully observe the workings of a multidisciplinary approach without being directly involved with the teaching aspects.

- The Skillsnet CPD program (5.5) involved the researcher taking multiple roles. Course developer, co-design team co-ordination (but not facilitation) and then when the course was launched, course contributor and facilitator. In the second year of the program the researcher was able to hand over facilitation fully to two other colleagues and to observe from the outside.

3.3 Prior Knowledge Survey

The use of surveying was appropriate throughout the research as it has been proven to assist in the collection of sufficient data to allow for a baseline assessment of the learners knowledge at the time of engagement with the research (Cohen 2007.). The intention here was to use a survey that gathered data relating to the learner groups understanding of sustainable design and development at the beginning of their involvement with the specific research case study or new curriculum development that they were involved with. The data would then be used as a baseline for their prior knowledge by which to assess their learning over the study period. It was intended that the survey provide additional inferred information about the level of knowledge of the learners and about the demographic of the case study groups.

It was envisaged from the start that the case study groups would be at different levels of progression in their professional development; undergraduate, postgraduate and industry experienced and it was intended to use a similar base line survey to attempt to establish similarities and disparities in the prior knowledge. It was chosen to work predominantly with anonymous surveys in paper format as these encouraged participants to be honest and open in their responses but also to consider for a discreet period of time their levels of knowledge. An online electronic survey package was rejected on the basis that it was too easy for participants to ignore and misrepresent themselves, while it may have simplified the data collation it was in the hand written nuances of the paper surveys that some of the anomalies and further information surfaced. The Prior Knowledge (PK) survey format was designed to ensure both a set of closed response questions (Mc Niff 2006) and a Likert-type scale set of questions (Likert 1932). The closed response questions allow for clear unambiguous responses that are easily analyzed while the use of the Likert - type scale gives a degree of variability and allows for the respondent to admit to different levels of knowledge.

In some cases it was deemed appropriate to include the disclosure of personal or company details in the PK survey as this assisted the tailoring of specific elements of the case study to suit those identified participants. This was notably the case in the surveying of the SDI participants (as described in 5.5.5).

The survey data was collated into excel spreadsheets and analyzed by the researcher in a series of formats which included representation of responses using pie charts and bar chart visuals (see Appendix A). This summarizing of the data allowed for an overview of the sample groups to be gained in advance of the running of the particular case study.

It is important to note that the format of the survey was modified to include three survey types

- PK Survey for undergraduate design and business student
- PK survey for SME professionals
- PK survey for Design Professionals

(See Appendix A for details and data)

3.4 Exploratory Case Study Research

> In general, case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context.
> (Yin 2003)

The case study approach underpins all of the other approaches used in the methodology. It informs the action research and provides the basis for the feedback, the prior knowledge survey and the other research methods.

The use of case studies in the research was an obvious method to explore the possibilities for gradual modification in the way the undergraduate design students could learn about sustainability. It allows for the testing of various teaching and learning methods in a semi formalized manner. The case study allows the researcher to observe the results of the androgogical intents that are set out but it more importantly allows the researcher to be involved with the study. It would be difficult in any academic environment to provide the resources for a totally external observer to be present while all of the case studies are being pursued. This necessitates the use of action research and exploratory case studies together as a means of assessing the effectiveness of the research. The interpersonal interactions and the informal discussions that happen in a studio based learning environment often do not provide the clear metrics that are required to analyze overall learning outcomes. These are

provided of course by the design work that is submitted and by the formal presentations that are made during assessment however much more can be observed through the interplay between facilitator and student.

Robert Yin differentiates between exploratory, descriptive or explanatory case study research (Yin 2003). The case studies that were used here are exploratory in nature as they attempt to explore the possibilities for sustainable design education and to observe the ways in which the learner, at various professional levels, progresses their understanding. They do provide some descriptive and explanatory information but the scope of this is limited by the fact that they are quite situation dependent, i.e. they are based on particular student groups, geographical location and type of course. This would create a further challenge in scaling up the research findings to be applicable to a broader set of case studies.

The specific case studies that were used in this research include:

- Student Directed Project based learning projects
- Multidisciplinary Design Projects (MDPs)
- E-Learning Tools for undergraduates
- TU Delfts multidisciplinary module (Bootweek)
- The Joint Industry/Student Seminar Format (Reform Seminars)
- SME Sustainable Design Education workshop (Winnovate)
- CPD (Continuing Professional Development) (Sustainable Design Innovation)

The case studies were chosen to reflect a number of parameters that were important to the research. They were used in an attempted to understand and contextualise studio based learning, multidisciplinary learning and professional development. These case studies were also used as a vehicle to study the nuanced change in approach needed for these forms to be effective when applied to sustainable design. The case study boundaries included initiatives, projects, events and particular processes.

In the exploratory case studies undertaken here the intent was to evaluate the results so as to apply them to the theoretical model for a sustainable design education, it was not for the purposes of applying the results directly to a broader population. This emphasis is made clear by Yin, Tellis and other advocates of case study research (Tellis 1997; Yin 2003)
The use of case studies was appropriate in the context of the overall research in order to establish a number of benchmarks for what might be a current best practice for sustainable

design education. It was also used to explore the progressive learning capabilities of the students and the professionals within the context of SD, even if only over a short period. The exploratory case study method needs to be handled carefully in order to gain most value from the studies. There are limitations if the intent is not clear from the outset, there are further limitations when evaluating the outcomes if the researcher does not follow up with an evaluation stage (either by evaluating the learner responses to the case study or by externally evaluating the learning outcomes). The key focus of the case studies was to look for the opening of awareness and looking for signs that the design intent was changing with respect to including SD in their day to day thinking and work.

3.5 Curriculum Co-Design

The term Co-Design is used here to describe a collaborative approach to a development of design and in this case a curriculum for sustainable design. The Co-Design method encourages the facilitation of a group in order to achieve a communal goal. This method has been developed by Alastair Fuad-Luke In a series of workshops attended by the researcher (Fuad-Luke 2007) and in his latest book on *Design Activism* (Fuad-Luke 2009).It could also be described as stakeholder involvement or a consultative process in the design of any product, service or system.

> ***CoDesign*** is inclusive, encompassing collaborative, co-operative, concurrent, human-centred, participatory, socio-technical and community design among others (CoDesign 2006)

This method was chosen as a means to develop certain case studies (specifically the SDI curriculum and Winnovate workshop, see 4.7 and 5.5.3). The process was chosen as a means of including the wisdom and industry experience of the case study groups while mixing this with the educational methodology that was formulated to drive the research. The Co-Design method is normally applied in an actual design context to the design of products or service system, so it was a novel approach to use this as a method for developing appropriate curriculum and content. The assumption that the learner or a proxy learner should be part of the development process can be challenging in a traditional educational environment such as an IoT. The term ‘proxy learner’ is used here to describe someone who would represent the actual learners, individuals from appropriate professional disciplines, but would not be the ultimate students on the program.

Normally a course development team consists of a group of academics who project what is deemed as desirable in terms of curriculum content. This is then critiqued and validated by

internal and external review (mostly by other academics) as per the validation authority guidelines (HETAC 2005). The industry involvement in this process is often limited to one or two individuals who sit on the accreditation panel and unless the professional body has a strong mandate, which is not the case in the design field in Ireland, the actual needs of the professional learner can be under represented.

The Co-Design method applied here sought to widen this consultation process to include at a more holistic level the real needs of industry. The use of proxy learners in the form of a Curriculum Co-Design workshop complimented the curriculum development team's work which involved more detailed description in terms of learning outcomes, validation process, funding and professional body recognition.

3.6 Peer Review and Critique

The peer review method as introduced earlier refers to the use of papers published in peer reviewed journals, conference presentations and conference publications. Critique and less formal peer review was sought through the researchers own work colleagues, collaborating researchers and the supervisory team at BU. The intent here was to use the peer review and critique method as a type of 'sounding board' against which to evaluate the progress of the research. In addition the method seeks out robust criticism from the learner groups. The learner is often the most vocal (if given the appropriate forum) in terms of identifying the limitations of educational research.

The formal peer review process provides an academic rigour that encourages the researcher to be succinct in explaining specific areas of the research. Placing a paper in the public domain gives other researchers and experts the opportunity to comment on the research, the editorial process encourages modification and clarification of the written explanation and is rigorous in its own right. In the case of the two papers that were published in international journals, both were blind reviewed by a number of anonymous reviewers before being accepted for publication. (See publications resulting from research).

Presentation and conference publications provide further scope for feedback from other conference attendees. The EESD, RAE, Sustain 07 and DEEDS 08 conferences give excellent access to key individuals in the fields of sustainable design education throughout Europe and the UK (see 2.6). This networking was a valuable means of developing a broader 'community of practice' through which the research was able to be critiqued (Wenger 1999). This community of practice is equally important to any educator and also to the student. In the context of this research they were separate but it was clear as the research

progressed that the boundaries between educator and student are blurring. (See 8.2 for further discussion on this)

3.7 Interview

One of the critical evaluation and research methods used as part of the research was the conducting of interviews. Interview can be used to collect data for and from the case studies and selection of individuals were chosen on a strategic basis to be interviewed. These individuals were selected due to their involvement with the research under one of following headings:

- Graduated students now in industry *(Graduates who took part in early case studies described in 4.4.3 and Interview comments in*
- *Table* **3** *page 122)*
- Educational peers *(Interviews with lecturers from IT Carlow, University of Limerick, NCAD and Sligo IT, Auburn University, USA, and TU Delft, Holland)*
- Industry practitioners *(Interviews conducted with Winnovate partner companies and Design Partners, Bray)*

The interviews were set up using an 'interview guide approach' as described by Patten (1980) as cited in (Cohen 2007.). Where the topics and issues to be covered were specified in advance, in outline form (see 0 for interview questions). The researcher decided on the sequence and working of questions in the course of the interview. This approach allows for the interview to be conversational in nature while closing the gaps in the information required if they occur. The main limitations of this type of interview are in the omission of salient topics. The fact that the sequence of the questions can result in different responses also makes evaluation more of a challenge. These interviews were recorded using a digital audio recorder and some were conducted face to face and others by telephone. The recordings were transcribed and then interpreted (as in

Table 3 on page 122). In the latter cases (i.e. educational peers and industry practitioners) the interviews provided background and context to the research but the outcomes are not explicitly examined within the thesis. From a methodology perspective however they do provide valuable background information to the researcher on the perceptions within industry of education for sustainable development and on sustainable design itself.

3.8 Feedback Survey

The use of feedback surveys at the end of discrete case studies is a useful tool to assist with evaluation. When used alongside of the interviews it provides a reasonable metric for evaluating the immediate learning outcomes. It also provides a basis for reflection an improvement on the next cycle of the development in the action research (as in **Figure 10**). One of the limitations of the research methodology was in not formalizing this process early

on in the undergraduate case studies and relying too heavily on an end of module verbal feedback format. This, while useful in the immediate aftermath of a module, does cause difficulties when not recorded formally as in this case.

This limitation with feedback was identified at a midpoint stage and so a formal feedback using a written survey (see Appendix D) was put in place for the CPD case study (5.5). The responses and data from this case study have proven very valuable on a number of levels:

- Evaluating learning outcomes
- Informing changes and additions to the curriculum
- Assessing the learner satisfaction with the course
- Providing testimony for the continuation of the course
- Establishing the need for further learning initiatives
-

3.9 Timescale of Research

The research has focused mainly on learning strategies for design students and professionals, both design professionals and representatives from the SME sector. There was a peripheral focus on business and marketing as part of the multidisciplinary case studies. The language and terminology of sustainable design and innovation is the common link when developing these approaches. The specific learning strategies developed for each sector are nuanced but the general androgogical principles remain the same. The initial approach between 2005 and 2007 was to observe a number of existing models for sustainable design education and to apply them in a modified form to the Irish context (See 0, 2.6 and 2.7).

This developed in to a more involved development of new modes of multidisciplinary education. Similar study groups to those outlined in the earlier study were used as a benchmark but the addition of the SDI (Professional Designer group) was a critical element. In this case it allowed the research to develop not only the strategies for multidisciplinary education but also those for CPD in the post graduate realm.

The chronologic roll out of the research allowed for the development of the strategies in a progressive manner as outlined in Figure 11. (A more detailed timeline for the study as proposed at the outset is shown in Appendix E)

The research between 2007 and 2009 allowed the research to develop appropriate and effective methodologies and strategies for multidisciplinary education with respect to sustainable design and development.

The final thesis reflects the total research including the sustainable design education models and the multidisciplinary learning strategies for sustainable design. A qualitative assessment for each was deemed the appropriate means of evaluating the effectiveness of these approaches. It was possible to track the progress of a number of the participating undergraduates and business representatives as they took up positions in industry. In the case of the SDI participants a valuable network of peers has now formed into a critical mass and is being facilitated through the o2 Ireland Sustainable design network by the researcher.

The research as described here of course continues through a series of threads, many of these have the potential for further detailed study and development (as described in 9.5.) Current threads related to the research include the following:

- A collaboration with partners in Eco Design Wales, Kaospilots (Denmark), Tepui Design, University of Limerick and IT Carlow in the area of Sustainable Design Leadership
- The further development of the SDI module in to a full Masters program through Life Long Learning at IT Carlow
- The development of an additional Sustainable Design Module to compliment the integrated approach on the current Undergraduate courses at IT Carlow
- The continuation of the ReForm Seminars and other networking events on sustainable design in Ireland
- The introduction of specific sustainable design applied research through the Design CORE at IT Carlow through postgraduate research.

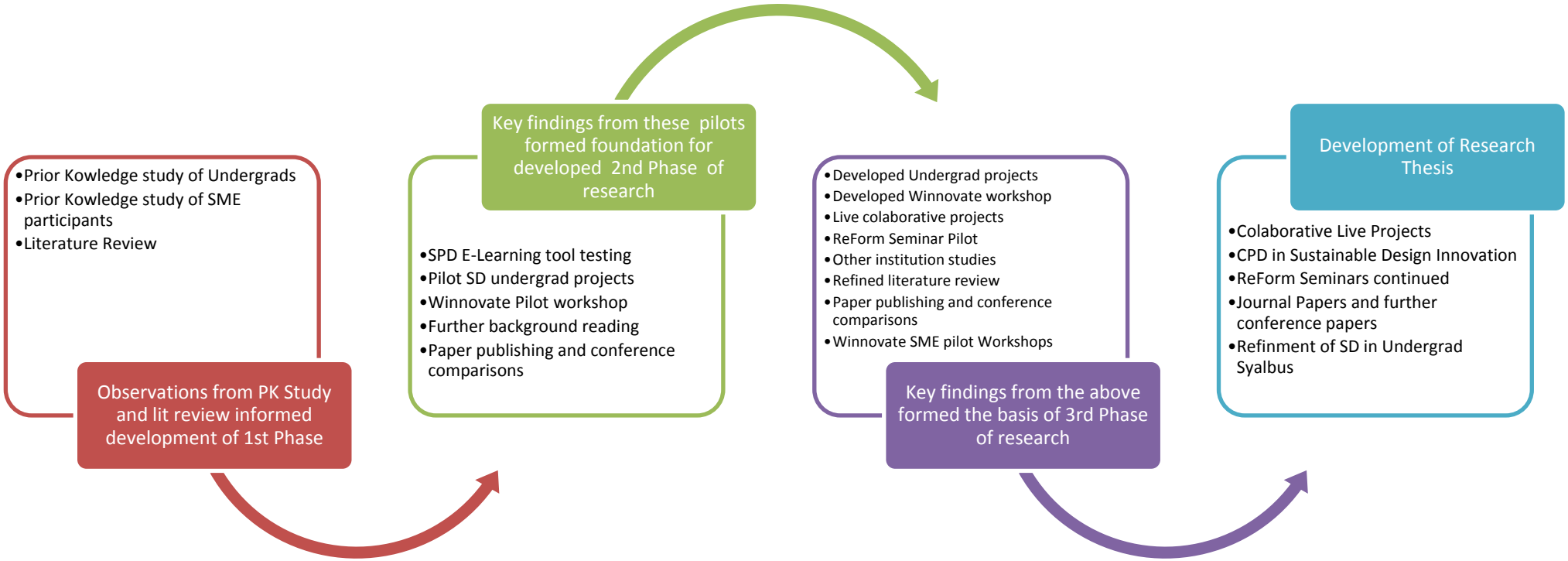


Figure 11: Key Phases of Research

3.10 Methodology Limitations and Overview

The research methodology used here attempts to provide a rigorous approach to the development and presentation of the thesis. It is intended as a process for examining current best practice, critiquing and evaluating in the context of the research question and then as a means of building new strategies within education. The methodology aimed at being both holistic and specific in using methods that examined, critiqued, informed and enabled the research.

There are limitations in how the methodology has been implemented. The research would be of lesser value to others if it did not outline some of the failings as well as the successes. There are real challenges around the issue of scalability of the research, applying it to other learning environments and in resourcing some of the strategies being proposed. The methodology outlined here relies heavily on access to multiple study groups. Not all researchers have the luxury of having access to both undergraduates, and professionals and even less have the opportunity to define how projects and initiatives run within the confines of an existing pre-determined curriculum. The opportunities for change within third level curricula are greatly confined within the resources that are available at any given time, financial constraints, staff expertise, physical space and pressures from non academic elements within education all make the development and sustenance of courses challenging. Many of these issues are outside the scope of this methodology but do influence the decision to use particular types of research.

There have clearly been some limitations also in the area of the quantitative study. While the research was intended to be mostly qualitative in nature it was felt that a degree of quantitative sampling was necessary also. This sampling (mostly done through the prior knowledge surveys) was intended as a means of establishing a baseline metric from which to gauge the learning of the participants. As the research progressed it was clear that quantitative metrics were less appropriate as a means of assessing learning in the SD arena. Qualitative exploration of the learners understanding and application of knowledge became more important.

Perhaps this is reflective of many of the challenges in current third level education. Quantity of graduates and quantity of students taking elective courses is often seen as the more important metric by those managing the educational systems. Quality of courses and modules is very much assumed as a given and there is an over reliance on the internal

quality structures within individual institutions. These quality systems are easily eroded when resources become tight and political pressures are applied to increase the numbers.

As is outlined in the thesis it has been possible to really develop new learning strategies for sustainable design and to successfully implement those in multiple educational environments; it has also been possible to place these in the public domain where they have been received positively. It is now an even greater challenge to continue to develop these initiatives and to continue the action.

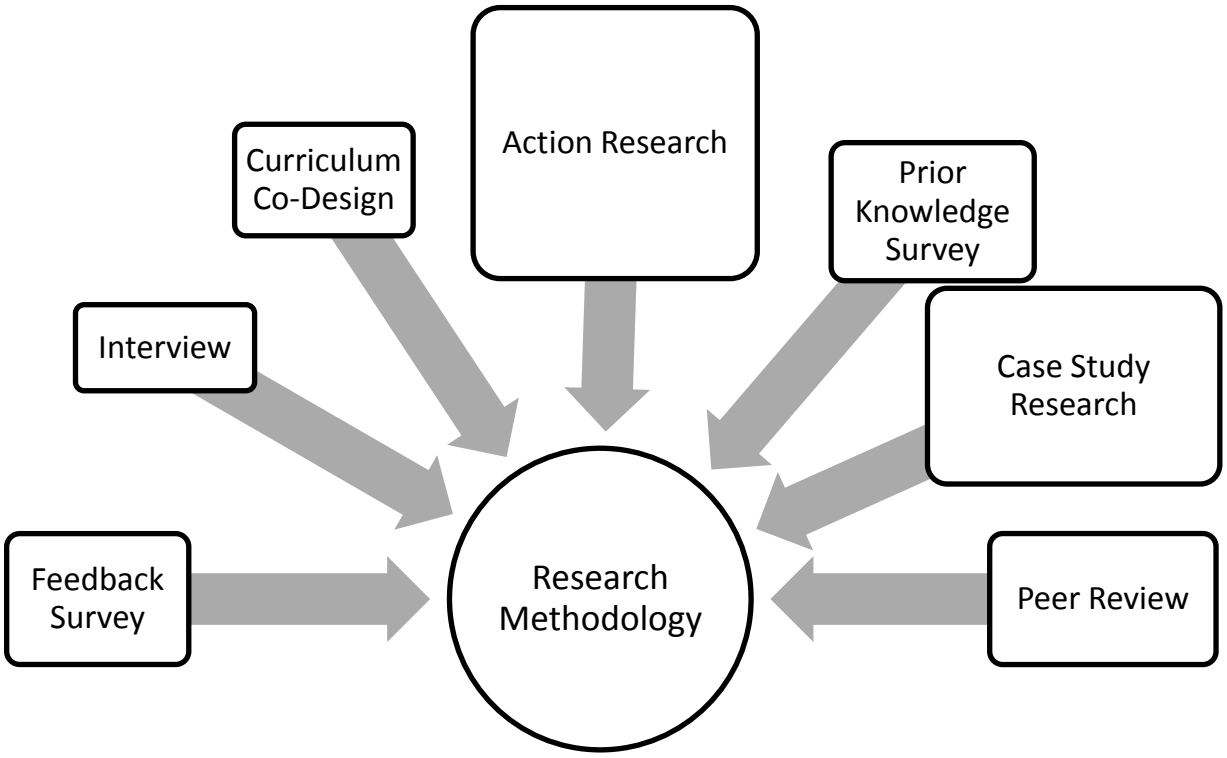


Figure 12: Research Methodology Overview

4 Initial Research Case Studies

4.1 Overview

It was necessary for the study to look at the existing trends in the introduction of sustainability issues and practice in the various design curriculums at third level. It was apparent from the pre-research phase that little had been done to even 'green' up the curricula of the product or industrial design courses in the Irish context. There were numerous examples of international models that had been applied to varying degrees of success and these formed one of the benchmarks of the initial study. There is some evidence that since the research has commenced there has been an increased awareness of sustainable design practices and the need for courses and professionals to develop their skills in these areas.

The second main investigation of the research was to look closely at the opportunities for developing continuing education tools for manufacturing and design based SMEs (Small and Medium Enterprises) in Ireland. The needs of this sector are wide and varied and while their impact on the local and international environment and society is significant they do not seem to have an effective means to continue the ongoing training of their employees. While this stage of the research was inconclusive and perhaps had limitations, it did provide the opportunity to test some initial androgological approaches with professionals.

The initial stage of these case studies undertook a series of prior knowledge surveys of the Industrial Design courses at IT Carlow to investigate the level of sustainable design/development knowledge of the students on the courses. This data formed the basis for the development of tools for learning/teaching SD.

The research built on the work done at Bournemouth University in the UK (in the School of Design Engineering and Computing) through the RAE VP (Royal Academy of Engineering Visiting Professor) scheme and sought to evaluate the suitability of the sustainable design web based teaching and learning tool for Irish design students. Other models for teaching and learning of SD in education were evaluated. This included studio based learning projects, seminar formats, and major project collaborations with SMEs. Preliminary reading, research and direct experience suggested that there are many wide and varied initiatives being introduced into engineering and design education worldwide.

The research included the piloting of a number of workshops/modules on sustainable design with the undergraduate students in Industrial design at IT Carlow and also with SMEs in the

South East of Ireland through the ‘Winnovate’ programme. The Winnovate programme was an initiative that the Industrial Design Department at IT Carlow and PDR Wales (National Centre for Product Design and Development Research) are leading to introduce the design process to a selection of SMEs in the South east of Ireland and South Wales. The programme involved a series of workshops and practical mentoring sessions with SMEs and part of the programme included the introduction of sustainability issues relevant to SMEs. The programme allowed for a sample group of ten to twenty SMEs to use as a case study for the research. The findings and experience gained through these aided in the development of the final thesis.

It was observed that for any sustainable design learning strategy to be fully effective in its implementation it needs the students to be able to work and communicate not just with their direct peers but also with non designers. It was indentified that this multidisciplinary aspect was difficult for most students to deal with in their first few years after graduating. The sustainable design elements of this are an additional challenge for new graduates and also more seasoned professionals. There is a steep learning curve in terms of communicating their thinking and professional perspective to their non design colleagues. In the case of the relatively new and emerging specialism of sustainable design the communication and rationalisation of the SD case in a business environment can be overwhelming. If a designer or engineer works in a company that is open to new ideas and has a drive to include sustainable development at its core then the task is obviously less of a challenge however these employers would seem to be in the minority. The tendency of any specialist (be they sustainable designer, engineer or business person) is to work in the consultancy role to maximise their effectiveness towards business however this can have limited impact as it takes the company to instigate the consultation in the first place. It can also be a costly approach and tends to be selectively used. Obviously this consultancy approach has its place but for the sustainable design and development agenda to be genuinely integrated in to everyday thinking of design, manufacture and marketing of consumer products it needs to be holistic as well as specialist.

The continuing research aimed to explore and develop effective tools and learning techniques for a multidisciplinary approach to sustainable design. The ultimate aim would be to enable graduates to ‘hit the ground running’ so to speak, in terms of their effective employment in industry.

The plans of research outlined below include the work done in the initial research and the proposed continuation to allow for the multidisciplinary educational models to be developed (as per Figure 1).

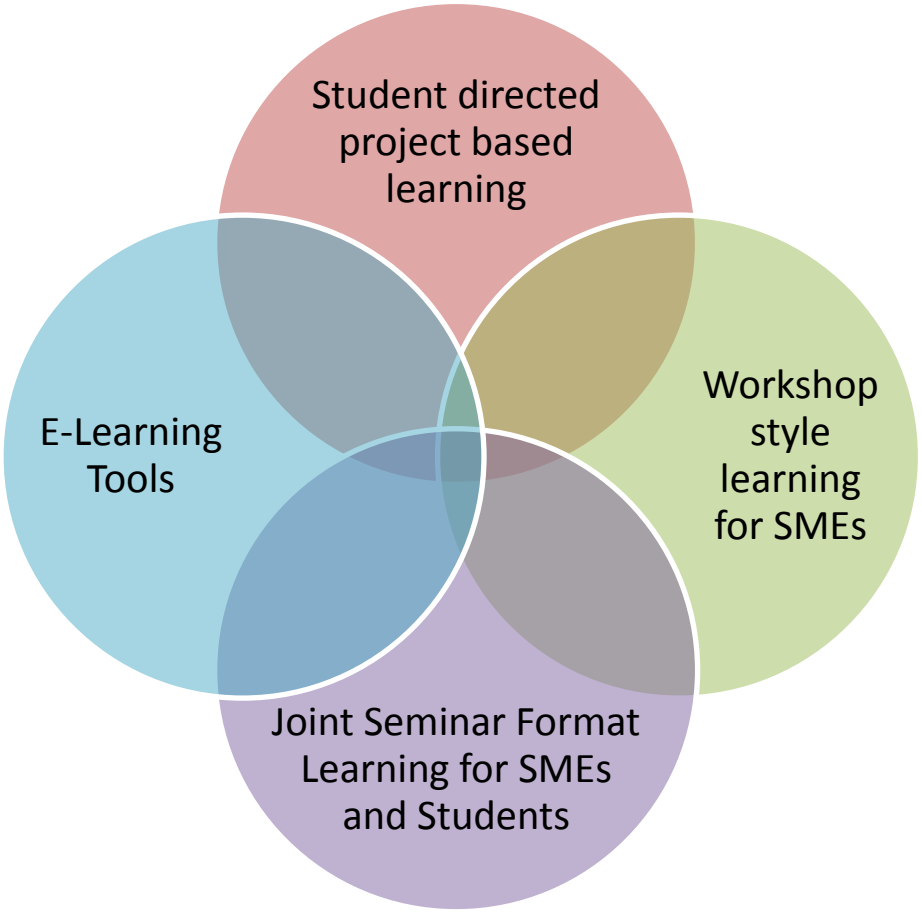


Figure 13 Initial Case Studies

4.2 Prior Knowledge Study:

4.2.1 Aim of Prior Knowledge Study

It was important from the start to establish a baseline from which to assess the students and the representatives from the SMEs. The intention here was to measure the current levels of awareness of the sample groups to key issues and terminology around sustainable design and sustainable development.

With the design background in mind a modified version of a sustainable development questionnaire developed by Surrey University for the Royal Academy of Engineering in the UK was used to assess different student groups' understanding of key issues surrounding sustainable development and design (Azapagic 2001
).

The questions fell under the following headings:

- Environmental Legislation, Policy and Standards
- Environmental Tools, Technologies and Approaches
- General Environmental Issues
- The rating of the students' importance of sustainable design as an issue to themselves, their work and the community as a whole.

The SME study group consists of four small companies in the South East of Ireland who were involved with the 'Winnovate Programme' that the Industrial Design Department at the Institute of Technology Carlow has just finished running. (The initiative was aimed at improving the NPD (New Product Development) of SMEs in the South East of Ireland and West Wales). The initiative was funded by the EU through the INTEREG III programme.

There was an opportunity through the sustainable design element of the brief for this programme to do a similar prior knowledge survey of the company's current levels of understanding of the key sustainability issues. The companies work in the manufacturing and development fields producing medical, marine, and waste management and packaging products respectively for both the international and local markets. None of the companies have to date developed a sustainable design specialism. The key representatives from the companies were given the questionnaires before their participation in the sustainable design workshop and follow up interviews were conducted as part of the ongoing research.

The broad assessment of the findings of the prior knowledge survey concluded the following (See **Error! Reference source not found.** for detailed data):

4.2.2 Student Survey:

The student experience demonstrated a knowledge orientation with awareness, understanding and attitudes highlighted. The students were aware in the main about topical environmental and social issues such as recycling, global warming and depletion of natural resources. The levels to which they could explain these issues in depth may be limited. The

students have an understanding of the issues around design and manufacture for sustainability however they are not familiar with key words and descriptions and find it difficult to differentiate between the more subtle elements such as cradle to grave rather than cradle-to-cradle design. A clear majority of students in all the classes assessed felt that sustainable design was of significant importance to them as individuals, the companies they may end up working for and for the world as a whole.

4.2.3 SME Study

The SME study group consists of four small companies in the South East of Ireland who were involved with the first round of the 'Winnovate Programme' that the Industrial Design Dept. at the Institute of Technology Carlow ran between 2004 and 2006, (The initiative was aimed at improving the NPD (New Product Development) of SMEs in the South East of Ireland and West Wales). The initiative was funded by the EU through the INTEREG III programme (ReForm, 2005).

There was an opportunity through the sustainable design element of the brief for this programme to do a similar prior knowledge survey of the company's current levels of understanding of the key sustainability issues. The four SMEs concerned work in the manufacturing and new product development fields producing medical, marine, waste management and packaging products respectively for both the international and local markets. None of the companies had at the time of the study developed a sustainable design specialism. The key representatives from the companies were given a slightly modified version of the student questionnaire before their participation in the sustainable design workshop and follow up interviews were conducted as part of the ongoing research.

4.2.4 General Findings

By contrast the professional experience emphasized knowledge, appreciation, and recognition based on practice considerations. The SMEs in the main have a slightly more practical knowledge of the social and environmental issues, as one would expect however there was limited appreciation for the relevance of the issues to their work. As with the students they have an appreciation for the Design for Sustainability issues generally but are not familiar with the key phrases and descriptions used by the experts in the field. All the companies recognize the need for their products to become more sustainable in nature but predominantly due to legislative pressures.

4.3 Student Study

The students surveyed here as a body are all currently studying Industrial Design on the undergraduate degree courses in Industrial Design at the Institute of Technology in Carlow. The course at the institute has been in existence for over twenty-five years and has gone through many transformations in curriculum and course content. In the main the nature of the course has been to provide students with a thorough understanding of industrial design as a discipline and to develop in them the necessary skills and competencies to work as either consultant designers or in house designers in a varying range of industries. Students typically progress to working as designers of consumer electronics goods and all types of mass manufactured items from toys to TVs. Many students use their skills in other areas of Design, Furniture, Interior Architecture, Product Engineering and Film and also in Web and Visual communications. In addition many graduates to not enter the professional design field at all but often use the skills and competencies learned in their education to become project managers, business leaders, entrepreneurs, etc. This shows the education provided through the course is reasonably holistic in nature and that the design process can be applied quite successfully too many other areas of commerce.

The norm in industrial design is to have the user as the central focus of the concept and students are encouraged to consider the impacts of their design concept not just on the single user but also society and the world as a whole. Issues surrounding the design of any mass-produced product include the interface with the user, the aesthetic, the ethical use of the product, (or unethical use as the case may be). The issues surrounding manufacture and choice of materials for any given product often become secondary to the human needs associated with a product.

The traditional educational model for industrial design differs significantly to its close neighbours in engineering and science. Design tends to be taught in a project based studio environment with animation and mentoring from peers and lecturers which is more closely aligned with the creative arts-based faculty than the conventional university model of lecturing and exam assessment. It is interesting however that this line of thinking and androgogical or pedagogical approach is much more in keeping with many of the key educational theorists (Jarvis *et al* 2003). It would seem that design as a studio based discipline has generally managed to successfully maintain the key educational objectives of small, peer group learning and learning by doing and reviewing approach. It would seem that anecdotally most engineering and science based undergraduate courses still rely heavily on a lecture based, learning by rote approach which arguably does not maximise the educational potential of the student. It is apparent through the research and the literature

review that many of the European third level establishments have identified that a move away from this format is a critical part of any sustainable development educational drive (de Werk and Mulder 2004).

4.4 Undergraduate Case Studies

4.4.1 Aim

The aim of the preliminary undergraduate case studies was to establish how the introduction of Design for Sustainability (DfS) criteria in to their project and curricula work would affect their education and their understanding of sustainable development.
The initial case studies all looked to existing models as outlined in the literature review (See 2.3)

4.4.2 Student Directed Project based learning

One of the key elements of the research to date has been to introduce the concept of Sustainable Design in to the mainstream project base of the Industrial Design (ID) and Product Design Innovation (PDI) courses at Institute of Technology Carlow. The courses offer either level seven (ordinary level BA) and or level eight (Honours level BA) degrees. The courses are studio based in nature as with many design courses and they involve a high degree of self directed learning mixed with mentoring, facilitation and expert input from lecturers. Both the ID and PDI courses are placed within the School of Business and Humanities at ITC and this offers unique opportunities with respect to the multidisciplinary models that are outlined later in the chapter.

The specific models and methodologies were developed for these groups of students by introducing a specific set of sustainability briefs in to a range of briefs that third and fourth year students were given to work on for their final year works. The duration of the projects was seven months respectively.

4.4.3 Third Year Group Project (ID)

The brief given to the third year was loose in nature offering the group of four students a statement from which to develop their own final design brief and product direction. The fourth year Honours students developed as part of their self chosen directions a sustainable design philosophy which applied to their product concepts.

The specific sustainability statement/brief for the third year group project (run between September 2004 and May 2005) was as follows:

> **Crude World**
> Modern living requires an energy source, which has finite limits. The myriad of products designed for western domestic, work and play markets consume at an alarming rate and most are dependent on a complex infrastructure of supply services. Maintaining current lifestyle values and expectation reshape the product in an environment beyond a crude horizon.
> (From Brief developed by de Eyto and Deevy, 2005- Appendix F)

In this case four students worked as a group, initially to undertake broad subject and market research. They identified through their research findings key product opportunities and over a number of weeks developed a series of concepts that might address the design brief that they had developed from the statement above. The most viable concepts were chosen by each student with the consultation of the lecturers to present a final suite of product concepts. These concepts were developed through a traditional DFMAD (Design for Manufacture, Assembly and Disassembly) stage and detailed up as Presentation models with 3D virtual models, technical drawings and full materials specs. In addition, a full marketing plan was produced for all of the products.

The students concerned developed a proposal for a suite of 'Powered Gardening Products' for domestic use in a communal environment (housing estate or similar). The concept negated the need for individuals to 'own' their own product but allowed them to buy into the use of such products as they require along with a communal charging system for the products.

Ultimately the students developed the product concepts from first principles in a holistic manner looking at all elements of the products manufacture, use, distribution and marketing as well as the critical issues of Lifecycle use and disassembly of the products.

4.4.4 Fourth Year HDP (Honours Degree Projects) (ID)

The ReForm seminar which was run in November of 2005 (outlined later) proved to be a catalyst for some further research case studies. In this instance the second round companies who were enrolled with the Winnovate Project were offered the option of collaborative work with a final year student through the vehicle of their major project. As both the companies and the students in question were involved with the ReForm seminar that year the sustainability issues were fresh in their minds at the same time as the work was

commencing. The students in this case showed an interest in trying to put in to practice some of the theoretical and ideological issues they had opened up through the seminar.

The fourth year honours students were asked in this case study to build in a sustainability philosophy from concept, through research all the way to detailed design for manufacture, assembly and disassembly. From a sustainable design perspective this is the ideal model, i.e. considering all the aspects of a new product development with the sustainability of the product and system as a core element from the start rather than an afterthought.

For the purpose of supporting the research the standard input from lecturers throughout the duration of the project was complimented by two specific short lectures on sustainable design by this researcher. These outlined suggested best practices on concept development from a sustainability point of view and secondly a more in depth look at materials selection and the impacts of specific materials on the environment. It is difficult to outline all the outcomes of each of these projects but of the thirty-two projects all the students were able to varyining degrees of success to develop their conceptual designs in to realistic solutions which showed high levels of eco-innovation and sustainable thinking.

Some of the student works (as shown in Figure 14) and included a high focus on materials selection. Environmental, social and economic considerations were key here but in conjunction with aesthetic and user friendly materials and forms. The use of the recently acquired CES (Cambridge Engineering Selector) (Granta 2009) proved an interesting addition to the standard background knowledge of the students which they have developed throughout their degree.

For the first time in many HDPs we see the students using such interventions as:

- The use of specific bio-polymers (for end of life considerations)
- Aluminium alloys (for weight reduction to increase efficiency and reusability)
- FSC (Forestry Stewardship Council) certified timbers in furniture and home wares.
- Low or no VOC (Volatile Organic Compound) lacquers and finishes
- Water based and sintered coatings on metals rather than high solvent based alternatives.
- The selection of power sources for some of the products with bio-diesel engines, PV (photo voltaic) solar chargers and re-chargeable systems being considered.

Many of the final solutions included attempts to address the social considerations of the product from manufacturing through to innovative suggestions on the sale and distribution of the products. Leasing rather than owning of some products was considered to allow for responsible maintenance and extended life or product take back possibilities.

The students themselves chose to highlight the sustainable design thinking of the HDPs through their end of year public exhibition which they entitled “Design for a Sustainable Future”. To highlight this each student dedicated part of their presentation board to a short paragraph with their own sustainable design philosophy with respect to the concept and their own professional thinking. The philosophies in the main were well justified and the students ability to defend their thinking was an interesting outcome of the study. Should the students in question carry this or a similar philosophy towards their work practice in to industry there will be a seed change in thinking as they influence their co-workers and companies.

As outlined previously, fifteen of the thirty-two projects were undertaken as ‘live projects’ with the second round SMEs from the south east of Ireland as a final outcome from the Winnovate programme. The students who elected to work in collaboration with an SME gained real practical and effectively experienced the constraints and realities of a client/consultant relationship under the guidance of the lecturers. From a sustainable design perspective this meant that the student and the client had to consider practical, realistic solutions with an ideological input from the start.

The key observations from this type of learning include the students’ obvious enthusiasm for a brief they have developed themselves and their ability to thoroughly defend and justify their design solutions. This was shown in their assessment presentations and tutorials at all stages of the projects. The ‘learning by doing and reviewing’ approach ensures that the knowledge, skills and competencies gained in the exercise are applicable to other areas of work and not specific to the use of one programme or specialism. For those working with SMEs directly on new product innovations the results for both the student and the SME involved were significant in illustrating the possible application of sustainable design thinking throughout the design process.

Figure 14: Stephen Bateman (HDP): Industrial Food Waste Composter

Figure 15: William Redmond (HDP) Building Site Heavy Lifting Assistance

4.4.5 Androgogical Intents and Observations

Both of the undergraduate research examples outlined above fit loosely within the three theoretical learning and research models described previously (Kolb, Bloom and Rhea). It is obvious in this context that no single model can account for the complex interaction involved between the learner, their peers and their teachers. The difficulty once again is that the model is not linear or definitive as it constantly develops and adjusts based on the learner's needs and experience. The teacher or animator in all cases needs to have the ability to

adjust the curriculum and delivery to account for these variations. Overload, boredom, fatigue, group and personality dynamics are amongst a few of the variables that students and teachers alike have to be able to deal with as the projects progress and as per Kolb's cycle the possibility for improvement is always there as the models are run for a second and third time.

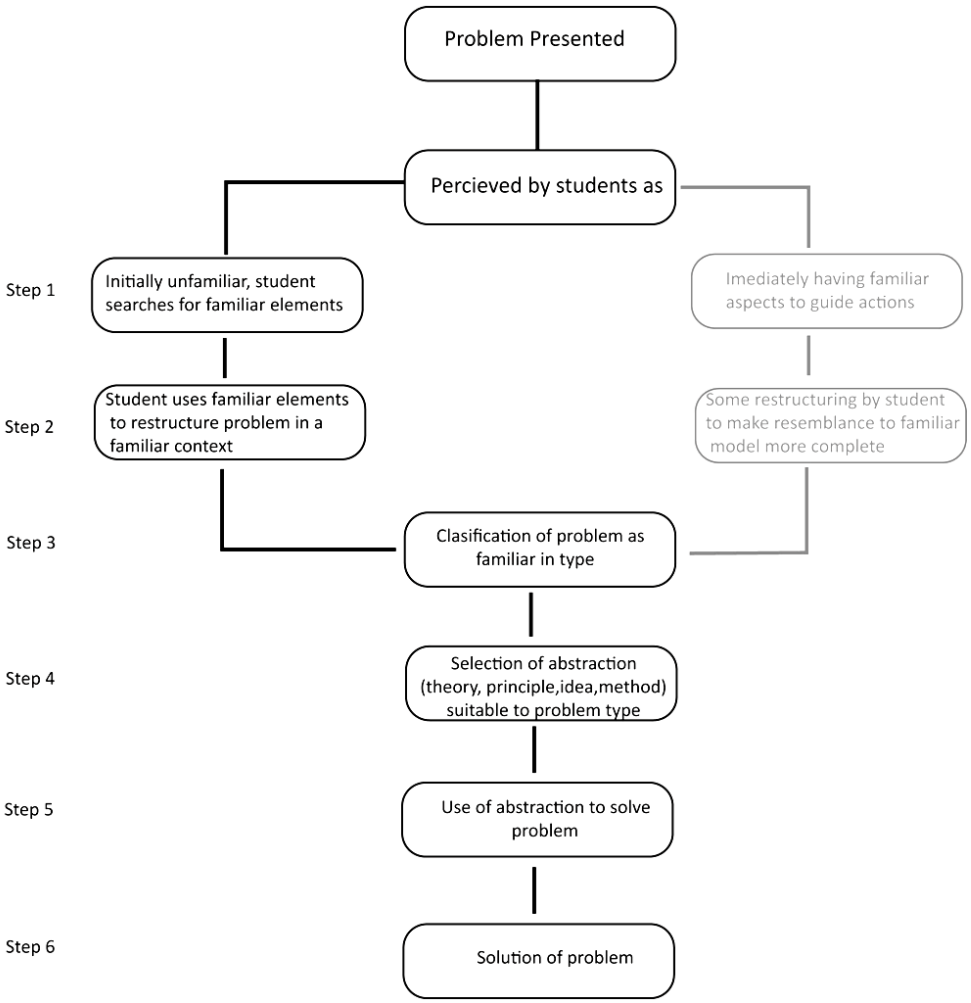


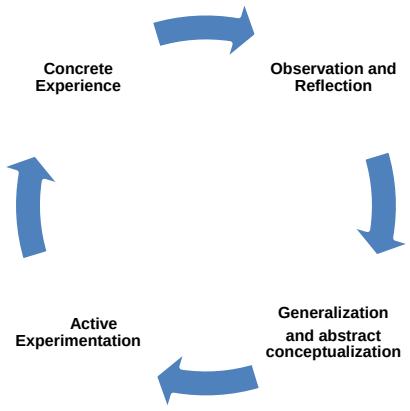
Figure 16: Undergraduate studio based projects

-Tend to follow the left hand path in Blooms learning process-

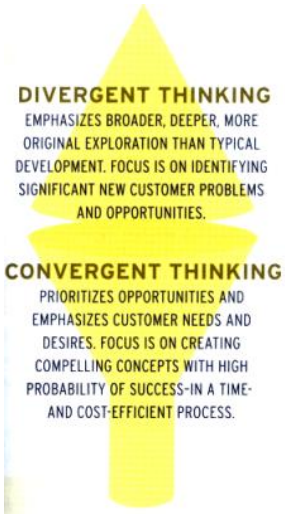
From an androgogical perspective these case studies sought to test how the existing studio based project would facilitate a specific SD focus. This methodology had been developed previously as a self directed learning approach to studio based work. The offering of a specific sustainability statement, in the third year case, or the development of a personal sustainability philosophy with respect to the HDP, allowed the students to take the presented problem and follow the left hand stages of Bloom's learning diagram (see Figure 16). The

students in both cases perceived the problem as unfamiliar (step 1) and sought to contextualise it through their research phase. Once they had developed a basic sustainable literacy they then sought to apply this through a version of Rhea's divergent/convergent thinking model. This is traditionally pushed by the lecturers as a critical post research activity for the design students. If the student fails to actively pursue this lateral thinking stage then they often continue to progress through the stages in blooms diagram but fail to make any real innovative breakthrough. This is where Bloom's model is limited in addressing the creative elements of design practice. The use of abstraction as he suggests in steps four and five of course could be deemed variations of the creative process but abstraction of existing theories, principles, and methods only go so far. Abstraction of ideas on the other hand does lead often to creative and innovative outcomes.

The third year 'Crude World' group were able to abstract and modify various understandings about existing garden products and mix this with their understanding of the sustainability aspects of the statement to formulate a view that a SPSS (sustainable product service system) approach was one solution to the problem at hand. Creatively this took a spark somewhere in the lateral thinking stage for the groups and the individual students to realise the link between SPSS and individual non owned products. It is these kinds of complex processes that best address many of the issues around sustainable design.



(Kolb 1984)



(Rhea 2003)

The fourth year HDPs are more difficult to assess from a learning perspective as they are the culmination of a degree students four years of experiential learning. The stages are similar to those described above but the complexity of the decision making that the student makes over six months is greater. The introduction of the live project element afforded the

opportunity for a multidisciplinary aspect and this was clearly beneficial in the main. The HDPs can be more closely aligned with Kolb's learning cycle as in all cases the students have been through a version of the process a number of times during their degree education. They could be described as having concrete experience and to have observed and reflected upon previous experiences. In the specific case study outlined here there was a deliberate attempt made as part of the research to influence the four stages described by Kolb. The observation and reflection stages were influenced directly by the ReForm seminar which was timed to coincide with their research phase. This afforded them the opportunity of considering how the approaches that the expert speakers in the ReForm seminars advocated could be then abstracted upon to apply to their HDP works. In the case of many of the live HDPs this was further influenced by the involvement of the live company client who would also have attended the seminar.

Again at the conceptualisation phase in Kolb's Cycle the students were encouraged to follow the divergent/convergent Rhea model of lateral thinking. This provided them with viable opportunities for sustainable new product development. Of course this process of following the two models was not explicitly explained to the student as it was incidental to their study but the briefing and sequencing structure of the HDPs was deliberately designed with these stages in mind. The challenges occurred when the students started to move in to their detailed design phase. In this stage of the project they are encouraged to develop ever finer levels of detail in terms of the product and the PSS.

As the element of sustainability was new to their experience they had not been able to actively experiment with implementing LCT (Lifecycle Thinking) and or sustainable materials selection in to their projects previously and so the challenge was new to them. Inputs from the researcher were given at this stage in the form of personalised tutorials and lectures on pragmatic approaches. The difficulty with inputs from a lecturer is that they are almost always biased towards a particular sustainable product design strategy - waste minimisation, energy efficiency, resource management and social equity; however some input is necessary otherwise the student risks being too self directed. The subtleties of this input can only be gauged on the ground by a lecturer if they have sufficient time, patience and expertise to devote to each individual student. It is clear from the research that some students have the ability and aptitude to process complex mixtures of information and to see the bigger picture with respect to sustainability on the opposite end of a class there are often students who have limited capacity and drive to handle this complexity- for whatever reasons. The teaching methodology must be flexible enough to cope with these modalities. Academically 'weak' students are part of the realities of modern higher education and this research has aimed to

cater not just for the engaged, enthusiastic and highly able students but also to provide ‘just right challenges’ for those who have lesser capability.

4.5 Other Higher Education Workshops

4.5.1 Aims

The Aim of this set of case studies was to generate a clear picture of how the introduction of SD in to other undergraduate courses around the country would be perceived. It also aimed to give a parallel to the ongoing and more intensive case studies within IT Carlow.

4.5.2 Overview

As part of the ongoing research activity into sustainable design education the author and Muireann Mc Mahon a colleague from the University of Limerick, followed up on the work started with the ReForm seminars outlined later in this chapter. It was clear that a singular follow up day (with each institution) would at most open up the issues that had been discussed in the seminar and raise further questions, however in order to be as pragmatic as possible the follow-up sessions in the individual institutions were developed as information sessions followed by active participation workshops.

To better gauge where both groups of students were placed in terms of their prior understanding of sustainable design it was prudent to undertake the Prior Knowledge survey, this same survey had been used in the previous research conducted on samples of Industry and IT Carlow design students and had proven useful as a benchmark from which to start activities. The Prior Knowledge (PK) survey focuses mainly on the students understanding of key terminology and strategies on the environmental side of the sustainable design debate. The conclusions with respect to both of the student groups are outlined below in a description of the workshops conducted.

4.5.3 Sligo Institute of Technology (Industrial Design, BA)

In the case of the Sligo group the researchers assumed no formal prior experience from students in sustainable design, as their lecturers, in discussion, had stated that the students had not been exposed to any formal sustainability modules or projects previously in their course work. The PK survey indicated that the students in the main were familiar with broad public concern issues such as recycling, climate change, waste management etc. but not familiar with design strategies that might be useful in dealing with these issues. The students did rate the importance of SD highly in terms of both their own design careers and their

personal lives. In almost all cases the students felt that it was very important to the viability of their future employers businesses.

On this premise the content for the workshop was basic and outlined the fundamentals of sustainability, tracing the development and demonstrating how it could be integrated into the design process by showing a number of case study examples. The researchers followed up the short overview with active participation sessions to illustrate and expand on some of the issues. In this case the first breakout session was given to groups as an exercise in simplified LCA (Lifecycle Analysis) using four consumer electrical products. A feedback session allowed for groups to state their findings with respect to the products they had analysed and to discuss with the other students and facilitators the possible reasons for the results along with proposals for changes that might be made to the products to increase their environmental and social performance.

The second theoretical session outlined key strategies and case studies that might be employed by designers to achieve more sustainable products and product service systems. As the students in this case were from all four years of the industrial design programme the second break out session was designed to encourage radical thinking and forced connection solutions to specific design challenges. This session proved interesting as the students, although undertaking a creative design course, seem to find it difficult to think laterally when it comes to global and social issues. They did show an ability to look at technological issues and deal with them in a creative applied manner but again in the time allowed often the solutions are a bit naïve. This is understandable however as many professionals equally have similar difficulties when presented with lateral thinking exercises. In the entire daylong workshop in Sligo showed the students to be keen and willing to take on board new perspectives to implement in to their design toolbox and many of the students were keen to join the O2 (sustainable design network) global and local networks to further their engagement.

It was interesting to note that the students participated in the workshop on a voluntary basis; however there was only some involvement from the IT Sligo lecturers in this case. All of the lecturers that we met expressed an interest in the field of sustainable design but perhaps due to time constraints they were unable to participate in the workshop. It may not be directly linked but it is apparent that the IT Sligo students are one of the students groups that consistently fail to participate with the ReForm seminars over the past four years and this is perhaps due to the lack of engagement by the course in exploring sustainable design within their curriculum.

4.5.4 NCAD (National College of Art and Design, Dublin)

The workshop that was undertaken in the NCAD was of a different nature to that of the Sligo experience as the year four BDes Industrial Design students had been exposed to the concepts of sustainability by attending the ReForm conference. The students were all in the process of developing their final year projects (FYPs) and were working on self directed briefs (very similar in process to the HDPs described previously), Again in this case the researchers customised the activities to facilitate this process and the aim was to provide additional support to the FYPs through the development of SD philosophies and strategies for implementation throughout the design phases.

Once again it was important to assess their current level of knowledge using the Prior Knowledge survey and to fine tune the day long workshop to that level of understanding as much as possible. As one would expect the fourth year students indicated they had a broader understanding of issues such as product take back schemes, the WEEE directive, cradle to grave design and cradle to cradle philosophy. Interestingly in this case most of the students indicated that they had received no environmental education with respect to design. (There would seem to be no specific module within the NCAD course to deal with this aspect) yet despite this they have a good level of understanding of the language and issues surrounding sustainable design. It would be accurate to observe that they showed a reasonable sustainable literacy.

The day was started using a broad brush presentation on strategies and considerations for sustainable design at the briefing stage of a project. Some key case studies were also introduced. The remainder of the day was used to actively engage students in a group format to brainstorm, discuss and develop possible strategies they might employ with respect to their specific FYP projects. Lateral development of strategies and ideas were developed by each group and animated further by the researchers

The feedback from this workshop proved positive and students seemed to be more confident that they could implement sustainable design thinking in to their system and product proposals. The research allowed for a follow up visit to NCAD for their final degree show. It was clear from this that many of the students we had engaged in the workshop had successfully implemented very mature sustainable design thinking in to their design work. In fact one of the students won the Dyson student designer of the year award for her design based on an alternative concept for sustainable computing in the home.

The NCAD lecturers in this case study did engage in the workshop and subsequently NCAD took on the co-ordination of one half of the ReForm 07 seminar which proved extremely successful. There is a much clearer sense that the ID Course at NCAD has embraced the need for sustainable design at a holistic level within the course and they have continued to engage with the growing community of designers within Ireland who see this as a way forward for design.

Figure 17: NCAD students at work in SD workshop

4.5.5 Androgogical Intents and Observations

These two workshops allowed the researcher to look at what could be achieved with relatively blank slates in terms of SD education. As can be seen neither course nor institution had implemented formally any sustainable design in to their curriculum and yet in the case of NCAD the students had a sustainable literacy that was clear. There is no doubt that, given no direction or formal teaching in SD, traditional design students would (if they have a personal interest and curiosity) still engage with sustainable design practice. The self directed nature of many design courses allows sufficient space for students to explore topics and problems that they deem to be important within a society context. The difficulty from an androgogical perspective is that they may not get sufficient mentoring or expert direction in this exploration. Without further study and analysis of these types of students it is difficult to be conclusive but one would expect that the solutions and the practice that they develop in this type of learning environment would be of limited applied value to society, industry and the environment.

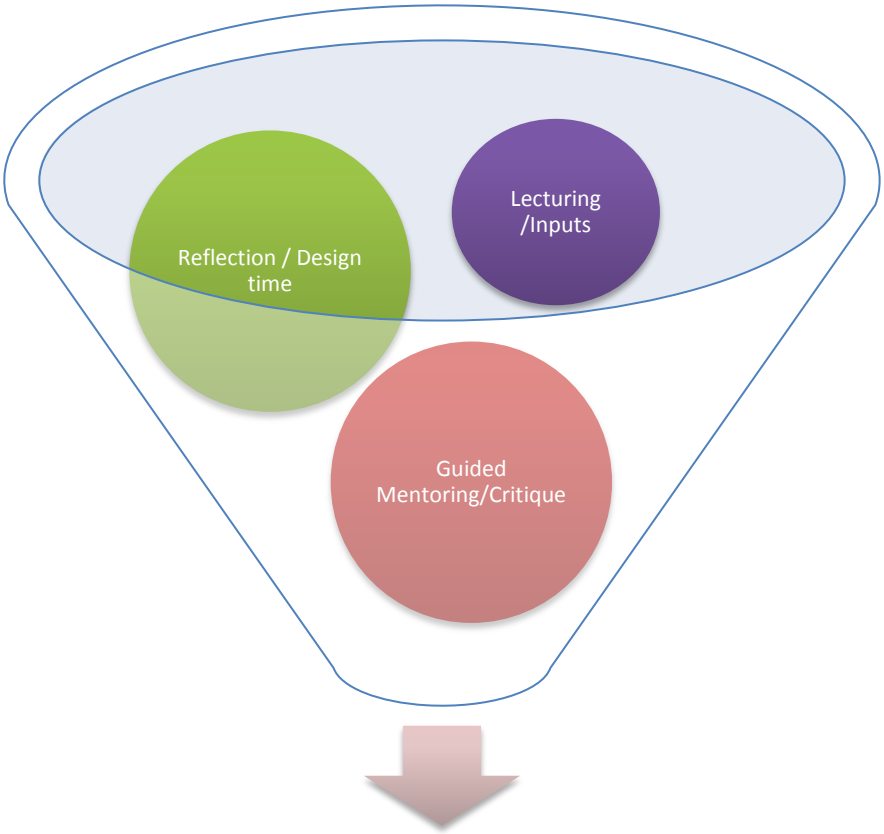


Figure 18: Design Education (as illustrated by the researcher)

Often with design courses there is an overly heavy reliance on this 'free' approach to studio based learning (i.e. that the reflection/design time is the larger part of the education). It is clear from the comparison of the various Irish courses that some institutions prefer to apply this model in a very liberal sense and that by default they have minimised the Lecturing and Input content of the courses perhaps to fit in with the teaching resources available. IT Carlow and UL (University of Limerick) on the other hand have focused on providing a more balanced approach where lecturing and other inputs are giving a high degree of importance within the syllabus (See above).

There is a constant debate in design education about the balance of inputs versus time and space to reflect and design. The 'Bootweek' case study (see 0) shows how a 'hothouse' multidisciplinary learning environment can allow for both in a confined timescale. Alain Findeli in his paper from 2001 argues that this shift in methodology was apparent from the first Bauhaus (Dessau) models in the early 1920s. This shifted again in the New Bauhaus

(Chicago) in the 1940s and once again Hochschule of the 1960s (Findeli 2001). These changes show how design education has shifted to reflect often the societal trends of the day. The Bauhaus model is widely accepted as being one of the first iterations of the design education model that most higher education uses. Irish design courses are not so clearly directed in terms of strategy but rather they respond in a more evolutionary manner to the societal and educational demands of the time. Sustainability is only one of such demands and perhaps we will see a shift over the next decade or so towards the inclusion of a sustainability focus in all courses.

4.6 E-Learning Tools

4.6.1 Aim

The intention here was to use, by way of case study, an e-learning tool for the introduction of Design for Sustainability in to a first year syllabus.

4.6.2 Overview

The e-learning website being used in this case was developed by a multi-disciplinary team for DEC at Bournemouth University and aimed to provide a support tool for the Masters in Sustainable Design and Masters in Sustainable Product Design courses at the University. It was felt that while the content of the site in some areas may be overly complex for undergraduate students, there were specific modules that could be applied to them and tested for their learning outcomes.

The test group in this case were the first year Industrial Design Students at IT Carlow. The specific modules included elements on introduction to Lifecycle Analysis and application of the same through an online project and a series of self-assessment quizzes. The modules were animated by the researcher for teaching and learning purposes and the modules were run over a period of two weeks. Specific hours were allocated to the students for computer access in addition to studio time devoted to discussion and development of design concepts. The students involved responded positively in the main to the site with the self-directed elements working well and good participation in the online elements.

The project involved the use of a simplified LCA package to assess the viability of a series of bottle designs. The students had some difficulty with the e-learning environment with minor technical glitches and difficulties operating some parts of the LCA software. While the e-learning tool does provide the students with a self-teaching medium it needs to be closely directed and designed as a support tool for project work. The LCA software, in combination

with the learning and teaching aspects of the site, allowed the students to access a much broader perspective of the effects of their design changes on the environmental and social aspects of their designs.

4.6.3 Conclusions

The E-Learning environment provides access to a broad variety of content and facilitates the students to learn at their own pace. There were in this case difficulties with the IT support and the access to the technology which frustrated the students and the researcher. It has been observed that this can be a common problem when introducing new technology to the classroom environment (see 5.2.3). There are huge opportunities with the use of E-learning in a blended learning approach for SD but great care has to be taken to ensure that content, introduction to technology and clear learning outcomes are defined and followed through. It should not be assumed that because students are deemed to be IT literate that they can also learn holistically from IT based systems- they still need facilitation and guidance at all stages.

4.7 SME Sustainable Design Education

4.7.1 Aim

The Aim of this case study was to explore the possibilities for introducing SMEs to the notion of including DfS in their new product development process. This 'knowledge transfer' approach between academia and industry has been encouraged by policy makers at a government level and it was intended to observe how industry would engage with such a process.

4.7.2 Overview

The SME study group consists of fifteen small companies in the South East of Ireland who were involved with the 'Winnovate Program'. The Industrial Design Department at IT Carlow ran this program in partnership with the National Centre for Product Design and Development Research (PDR) in Wales from 2004-2006 (The initiative was aimed at improving the new product development potential of SMEs in the South East of Ireland and West Wales) (Winnovate,2006). There was an opportunity through the sustainable design element of the brief for this program to complete a similar prior knowledge survey of the company's current levels of understanding of the key sustainability issues.

The SMEs involved work in the manufacturing and NPD fields. None of the companies had at that stage developed a sustainable design specialism. In fact for many of the companies involved it was a first engagement with 'Design' in a formal sense. The key representatives from the companies were given the questionnaires before their participation in the

Sustainable Design Workshop and follow up interviews (Post Program) were conducted as part of the ongoing research.

The broad assessment of the findings of the prior knowledge survey concluded the following:

- By contrast (with the students) the professional experience emphasized knowledge, appreciation, and recognition of sustainable design and development based on practice considerations.
- The SMEs in the main have a slightly more practical knowledge of the social and environmental issues, as one would expect however there was limited appreciation for the relevance of the issues to their work.
- As with the students they have an appreciation for the design for sustainability issues generally but are not familiar with the key phrases and descriptions used by the experts in the field.
- All the companies recognise the need for their products to become more sustainable in nature but predominantly due to legislative pressures.

Figure 19: The Winnovate Project Logo

The ‘Winnovate’ workshop was run as part of the first round of work on the project in 2004/05. It included a short presentation on some of the key considerations around sustainable design and an introduction of the concepts surrounding the use of materials and mixing of materials in the manufacture of any given product. The workshop was run over an afternoon session with a twenty minute presentation and a three hour long dismantling and discussion exercise in ‘round table’ format. It was felt that a practical, hands on approach would have most appeal to the four companies, as at this stage in the Winnovate project they were already suffering from theoretical fatigue. The presentation was kept to an absolute minimum in order to outline the key concepts. The main element of the workshop involved the use of a Product Dismantling Exercise (from the Bournemouth University SPD website) The companies were given a new jug kettle and asked to dismantle its component parts and packaging using a series of questionnaire sheets and some quantitative analysis. The exercise provided the companies with a focus on which to develop their discussions around the key issues.

The main areas discussed included:

- *Materials usage* - environmentally sustainable pros and cons of various plastics, metals, solvents and packaging options.
- *Materials mixing and separation* - post use, sourcing of materials and manufacture from third country locations and the ethical and quality issues involved. The newly introduced WEEE and RoHS EU directives along with other waste minimisation issues and legislative issues were discussed at this stage.
- *Opportunities for re-design of the product*. The kettle provided many obvious areas for improvement and re-design both radical and superficial. The companies were surprisingly creative when given free rein in considering viable alternatives.

4.7.3 Observations

The informal nature of the workshop style and the discursive environment works well with companies who are willing to take time out of their busy schedules to participate. All the company representatives commented on how valuable it was to be off site for only a few hours exploring opportunities and creative solutions with relative strangers. It provided them with the space necessary to stand back and assess the business they were involved with and how it might be improved either from a new product development perspective or through improving their existing product lines.

In the context of the educational theory the workshop structure fits in with the Kolb learning cycle thinking referred to earlier. There is room for development in the areas of concrete experience and active experimentation. The logical development would include a follow on project that the representatives would work on within their own companies. This would encourage the application of the knowledge in sustainable design and abstract problem solving in this context. Time and commitment as well as the practical ability of SME representatives to engage fully in any CPD programme are all factors that will need consideration in developing this model. The issue of reward or recognition of training has not been addressed here but may again be part of a suitable developed model for CPD in sustainable design.

Figure 20: Winnovate Sustainable Design Workshop 2005

5 Developed Case Study Models

5.1 Overview

This chapter aims to show the specific outcomes of the research in terms of its contribution to knowledge and to educational practice in sustainable design and development. The chapter outlines the series of case study models developed over the five year research period and more importantly the strategies developed to support them.

As has been outlined previously in chapter 4 there were a number of opportunities exploited in terms of developing models that addressed the needs of three main groupings of learners, these were:

- Undergraduate students (from design and other disciplines)
- SME professionals
- Design professionals (in the context of continuing professional development)

The focus of the research at this stage was to develop an innovative approach to Continuing Professional Development (CPD) with respect to a multidisciplinary participation. This became apparent through the initial stages of the research as one vehicle through which a new learning model might be developed. Many of the findings from the primary phases of the research with undergraduates and SME professionals were distilled in to this short course module so as to roll out a course that was both novel and unique as far as we can ascertain.

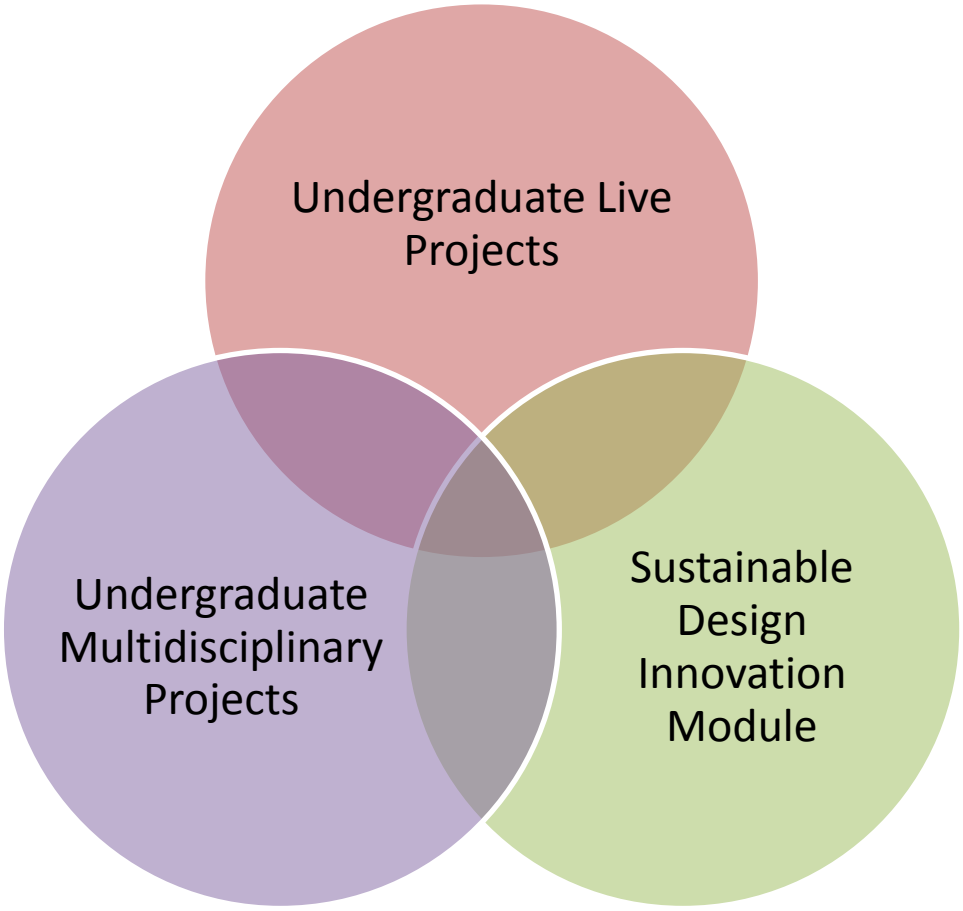


Figure 21 Developed Case Studies associated with PhD

5.2 Multidisciplinary Design Projects (MDPs)

5.2.1 The Need for Interdisciplinary Education

> Mixed discipline groups, cross-departmental and experiential groups from different academic and industrial levels are needed to allow for a more holistic approach to problem solving.
> (de Werk and Mulder 2004).

The issues surrounding sustainable development are extremely complicated with most specialists dealing their areas of expertise rather than the big picture. Hence, there is a danger that in the third level sector that students receive detailed analysis of specifics without being able to achieve joined up thinking as a final skill. The continuing focus on disciplinary learning is critical on one hand as it ensures specialism in areas such as design, engineering, marketing and architecture. The reality is that all these professionals will continue to rely heavily on team driven work in their professional lives. So it is critical that we, as educators, expose students to other disciplines and facilitate multidisciplinary learning through project work in the main curricula.

> Learning to share: to imagine that any one closed group could solve the complex problems we face today is folly.
> (Mau et al 2004).

Specialism in disciplines such as engineering and design allow for detailed expertise, deep thought and complex research. They develop a disciplinary literacy that enables the practitioners to communicate with each other on complex levels often leading to high tech – mostly incremental - innovation. The negative side to disciplinary specialism is the increasing focus on getting to know more about what is already known. This not only leads to increased specialization but also to 'Silo' thinking. This style of thinking is analogous to standing inside a large grain feed silo with huge capacity for storage (of specialist knowledge) but with little ability to share that capacity for storage effectively with the silo beside you, which is filled with another grain feed. You just do not think of it because the silo contains another kind of grain (alternative specialist knowledge) and you do not see it because the walls are not transparent.

Higher education, industry and government have a history of difficulties with respect to co-operation between their diverse and multidisciplinary specialists. Higher education has developed around schools (or silos) of business, engineering, science, humanities etc. which then developed smaller departments or 'silos' with ever more specialism (de Eyto and de Werk 2008). These stereotypes in discipline are generally re-enforced after graduation to industry and at governmental level. They increase the gap between science and the real world, keeping problem solving incremental and only within the disciplinary paradigm.

To really solve the sustainability problems that currently occur we need to mediate the trend of overspecialization and reconnect (future) engineers and designers to the outer world and themselves. As is pointed out, losing track of other disciplines starts at the university. This is the place where we need to start to reconnect disciplines and develop a communal sustainable literacy that allows specialists to communicate effectively.

It is apparent from the research outlined here that huge opportunities are being lost due to the overspecialization of disciplines through the re-enforcing of stereotypes in traditional educational modes. There is little doubt that the EESD (Engineering education for sustainable development) (see 2.6.3) and other initiatives in education such as the DEEDS (Design education and sustainability) (see 2.6.1) project have and will greatly improve the quality of delivery of education in sustainable development. Despite this the experience of the researcher with the traditional models has been of compartmentalised learning where the

learner adequately learns by studying the many theories on their chosen discipline. The theory unfortunately is rarely applied to real world scenarios. The meaning and potential to really get to sustainable development is not fully understood, as it is barely discussed, hardly applied and only ‘learned’ and forgotten after the exams.

There was an opportunity to test a number of multidisciplinary project initiatives in the context of the research over a three year period starting in 2006 (both of these initiatives are still ongoing and are constantly under review). The projects sought to look at how a multidisciplinary approach to sustainability could be achieved in a purely higher educational context. The scope of these two initiatives was limited to groups of undergraduate students that were able to be closely managed through formal coursework and clear deliverable project phases. In each case the students worked in mixed discipline groups and a concerted effort was made to form groups that had a positive mix of not just discipline but also gender, cultural background and age. The group selection in the case of both initiatives was managed not by the students but by the facilitating lecturers.

5.2.2 Aims

The aim of developing the multidisciplinary case study models was to illustrate that, when students and professionals learn together or in mixed groups about sustainable design, they learn to think more holistically. These case studies also set out to show that by learning in a multidisciplinary environment, students are better able to cope with the complexities of sustainable development.

5.2.3 Inter Institutional Project Case Study:

This project commenced in 2006 between IT Carlow (Industrial Design) and GMIT Letterfrack (Galway Mayo Institute of Technology) (Furniture Design).The project was undertaken as part of two separate modules that are run concurrently at the institutes. The IT Carlow project fits in to the MDP2 module that third year Industrial Design students must take as part of their BA ordinary level award year. On the GMIT Letterfrack side, the project fits in with the product design module taken by fourth year BSc in Furniture Design and Manufacture students.

The project has now been through two iterations over two years and has varied in terms of the brief that is given to the groups. The groups are normally made up of four to six students each. The project involves a day and a half on site in each institution with an overnight social slot which allows the groups to get to know each other outside of the formal learning

environment. This mix of travel, formal group work and social interaction allows the groups to bond relatively quickly. The onsite face to face sessions are separated by a three week interval where the student work remotely in their respective institutes and communicate with each other and their group through web based media (MSN, Skype, and E-Mail) and telephone (Microsoft 2008; Skype 2007). The project sought from the start to utilise the new e-technologies in an effort to provide multiple communication channels for the students to facilitate meaningful group work. There is, as with the e-learning tool (outlined later in 4.6), a learning curve associated with even these students (18-25 year olds on average) using the new technologies and it is fascinating to see how their supposedly 'wired' generation still have issues around using technology effectively. There is a tendency for individuals to use the technology limitations as a barrier to communication and the standard issues around engagement in group work can be exacerbated by remote e-group work such as this.

In an attempt to facilitate the group work the lecturers involved set aside specific time slots for 'Skype meetings' and specific deliverables for concept presentation, development and final presentation stages. The groups were encouraged to use whatever medium they found most effective over the duration of the projects. Web cam Skype meetings proved to be an interesting novelty initially but in the group situation (as distinct from one individual talking to another) the students found it to be of limited value – Initially, webcams, data projectors and speakers along with Skype accounts were set up in each studio with specific web meeting times.

In 2006 the brief focused on the development of sustainable street furniture design. The focus in this case was on allowing the distance collaborative learning pilot project run in March/April 2007 with possibilities for further project in Spring 2008. This project seeks to utilise new e-technologies (web based learning, Skype and video conference and instant messaging) to facilitate the mixed discipline project work with a specific sustainable design brief.

5.2.4 Observations

This particular case study showed clearly the advantages of bringing students off site and out of their normal learning environment. The students from both institutes gave very positive feedback and showed openness to working in a meaningful way with others that were not from their immediate peer group. The time constraints and logistics involved with organising this type of project can be mitigated by using virtual communication tools as described but they clearly do not substitute adequately for face to face collaboration. In an organic learning environment such as a typical studio the students need the constant interaction and 'pressure' from peers to engage fully. The 'virtual' studio allows students to turn off their interaction with a group and it

can be challenging to get them to take responsibility for their group management when this happens.

5.2.5 Intra Institutional Work

Within IT Carlow it has been possible to trial over two years a sustainable design focused MDP (Multidisciplinary Design Project) working with the third year BA in Marketing Practice Students and the BA in Industrial Design Students during October 2006 and October 2007. This exercise allowed the researcher to test the specific models of group based learning and project based collaborative learning with the two disciplines of students and lecturers. The students in this case study were formed in to mixed groups of six to eight students. Due to the class sizes in the Marketing Practice Course the groups have a larger proportion of Marketing students- typically five marketing to two design students.

In these case studies the groups were engineered to provide a mix, not only of discipline, but also of gender and culture. It so happens that the marketing and design courses attract a large number of Erasmus (EU 2009) exchange students from other European institutions.

The briefs given encouraged the groups to develop both a design and a marketing strategy for a given NPD (new product development). This involved the development of packaging and promotional information to support the NPD and to highlight its sustainable design improvements (see Appendix F for full brief).

There were limitations with respect to this case study specifically as there were problems with the number of students taking the courses. It has been run a number of times with variations to the management of the group structure however there are risks if the group management is not carefully facilitated as negative experiences between the disciplines can develop. There is some evidence from this case study that students had real difficulties working with students from a radically different course and certain stereotypes around Marketing and Design were developed in these cases.

Figure 22: ITCarlow Marketing and Design Students at Work on Collaborative Sustainability Project.

5.2.6 Observations

In this case the projects showed a number of key outcomes. Students who are given the opportunity to engage on project work with other disciplines while in their undergraduate education develop different skills. Similar observations as those outlined in 5.2.5 were made but notably the intra institutional projects showed that students are less diplomatic and tolerant of students on other courses. There is a risk that mixing disciplines can re-enforce stereotypes between disciplines. There is a longstanding debate about who should manage the new product development process- the Designer or the Marketer? Students have understandably less experience than their professional colleagues and so are more inclined to blame these stereotypes for the failures in group communication etc. A number of incidents occurred during these projects that showed that it can be difficult for undergraduates to see where their expertise ends and their personal perceptions took over. The teaching content needs to be moderated and adjusted to include a broader range of topics and examples which then act as an instructional scaffolding for the students. Students from one discipline need to be able to connect with the issues of the other and vice versa, without this the issues become simplified. From an SD perspective the case studies clearly illustrated that students can tackle real problems and make interventions that address holistically the issues that a move towards sustainable development raises. This type of project teaches the student the value of

compromise and the need to mediate a solution that is holistic and addresses the needs of the customer, company and user.

5.3 Multidisciplinary Case Study, Bootweek with TU Delft 2006

5.3.1 Aims

The aim of observing and participating in this case study was to witness and learn from one of the current best practice models that exist internationally with respect to Multidisciplinary learning for SD.

5.3.2 Overview

As referred to previously in the literature review, the Bootweek, run by TU Delft (de Werk and Mulder 2004) was identified as one of the more innovative approaches being adopted by academia in terms of multidisciplinary education for sustainable development. The certificate has three elements to be completed; A two week interdisciplinary colloquium (run on a barge which travels around the industrial heartland of Holland); a theoretical series of sustainable development electives within the TU and a final integration or application of their learning in to their graduation project.

This researcher was fortunate to be invited to participate in one element of the afore mentioned module named ‘Bootweek’ (Boat week in English).Bootweek is a Multi/Transdisciplinary sustainable development module run by TU Delft on a bi-annual basis. The Course runs as a 4 ECTS credit course in two parts. The initial introduction of the students happens through the web based VLE (Virtual Learning Environment) ‘Blackboard’ prior to the physical meeting of the students. The boat week itself, runs from a Monday to a Friday and is a live aboard Dutch barge which accommodates twenty-eight students and a number of facilitators with a common lecture space and eating area. As mentioned earlier the five day intensive is followed by a lecture series and a week and a half module during which the student groups work on a project report together.

Figure 23: Bootweek Barge
- Provides the 'hothouse' environment for
Intense multidisciplinary learning-

Figure 24: Expert Lectures during Bootweek

Figure 25: Small Group Work during Bootweek

Figure 26: Industry Visit to Eco Incubation facility in Rotterdam

Figure 27: Group Work on Barge

Bootweek offers a special example of what is possible when disciplines are facilitated to learn together about sustainability. TU Delft resources heavily this module and in recent years due to its popularity the Bootweek has had to include a second boat to accommodate the numbers wishing to take the course. No doubt this format for education is not always possible in all institutions due to the resource implications but elements of the philosophy can be used in any strategy.

In the context of this research Bootweek offered a current best practice model for multidisciplinary education and the continued collaborative work with the researchers in TU Delft provided the opportunity to reference the work from this thesis with the initiatives and new developments in Holland.

5.3.3 Observations

General Observations:

- Students from mostly engineering disciplines get a genuine chance to interact in a multidisciplinary and interdisciplinary way with an animated PBL, active learning and lecture based mixed format.

- Learning styles include, PBL, role play, lectures, video, excursions to various appropriate facilities, group presentations, brainstorming, open forum discussion and debate and most importantly, non formal after session discussion.
- Participants are mostly masters' students but the common link is an interest in sustainable development and its various threads. Disciplines included Architecture, Mechanical Engineering , Electrical Engineering, Industrial Design, Environmental Engineering, Marine Engineering and Civil Engineering
- The course is open also to graduate students wishing to broaden their experience levels prior to masters.
- Mixed nationality, Course run through English and Dutch.
- Specialist lecturers come on and off board as required and travel to the boat by train etc. depending on its location.

Student Interaction:

- Students are fully engaged despite long hours of concentration.
- As long as format is varied few seem to get bored or lose interest.
- Stimulating discussion on all parts of the course even after hours
- Lively and heated but polite debate during sessions and deeper discussion in the 'spaces' between.

5.4 *Joint Industry/Student Seminar Format*

5.4.1 *'ReForm' Seminar Aims*

The ReForm seminars aim to be an introductory session to the main principles, philosophies and strategies in sustainable design with a different focus each year. With respect to the research they intended to explore how best to build capacity and dialogue at a national level with the educational establishments and industry.

5.4.2 *Overview*

The ReForm seminars bring together key national and international experts with representatives from various SMEs and professional designers in Ireland on a now annual basis. In addition students from the main product and industrial undergraduate courses around the country are invited to participate alongside of the IT Carlow and UL students. The format for the seminar encourages the interaction of the mixed student groups and industry representatives through discussion workshops that are interwoven with the key speakers' presentations. The objective is to expose the students to the difficult realities of sustainable design from an industry perspective and for the company representatives to avail of some of the creative and more idealistic free thinking of the students. The expert lectures combined with the targeted workshops allowed the participants to be immersed in sustainable design thinking for a full day, to share ideas and to understand the challenges and opportunities they face.

The specific speakers who have contributed over the four seminars have included: Alastair Fuad-Luke (author of the Eco-Design Handbook), Dr.Dorothy Maxwell (then director of the Environmental Policy Unit of Enterprise Ireland), Dr. Paul Butler (Materials Ireland) Dr. Frank O'Connor and Simon O'Rafferty (Eco Design Unit, Wales), Ab Stevels (Philips), Prof. Ezio Manzini (Milan Polytechnic), Gertjan de Werk (TU Delft), Simon Stringer (Leaf Environmental), Erik van Lennep (Tepui Design),Tim Allan (Locus Research), Ryder Meggitt (Element zero six), Brian O'Brien (Solearth), Prof. Michael Braungart (EPEA)

Over the four years to date the organisers have tried to ensure that the seminar is not only hosted in one of the participating universities, but spread around the country geographically to allow participation from a broader cross section of industry and students. In fact in 2007 and 2008 the ReForm seminars were co-located using video conferencing in two locations. This effectively allowed for the doubling of the participating numbers. In 2007 the seminar venues were in NCAD (Dublin) and UL (Limerick) with over seventy participants in each venue. In 2008 the venues were in IT Carlow and Cork IT. The use of videoconferencing also

allowed the seminar to have remote keynote speakers such as Ezio Manzini and Michael Braungart - both internationally renowned specialists in their respective fields.

5.4.3 Educational Overview and Intent

One can draw many observations from the use of a seminar format such as this however from a sustainable design educational perspective there were some that were specifically pertinent to this research.

The students, SMEs and design professionals engage well with a short format seminar on the basis that they can devote full concentration to the issues being discussed. They remove themselves from their everyday focus and take the time to consider the specific challenges that sustainability brings to design.

The seminar/workshop format allows for both broad and specific topics to be introduced in quick succession and for the participants to rapidly form opinions, action points, and observe case study parallels for their own work. This quick fire approach does cause some difficulties however as participants need time to reflect on the issues raised at seminars and the speed at which the seminar format takes place is often not so conducive to this. Seminars, like with academic conferences, give the opportunity to participants and speakers alike to test their views on an audience of peers. They are a vehicle for seeking feedback and presenting what others are thinking in a formal environment. This is an entirely different format to the studio based work that has been examined up until now. The public seminar format encourages speakers to crystallise and present their ideas in a coherent manner where studio work and design work generally can be complex and often needs time to describe. Multilayered work is difficult to communicate and as sustainability tends to be multilayered by default it is critical that listeners can absorb the information and contextualise it. A good speaker who presents well is often very different to an academic or industry expert; often the two do not coincide.

In the recent ReForm 08 seminar written comments were sought from the SDI participants (described later) on the format of the seminar and the quality of the speakers, many were highly critical of some of the speakers in terms of communicating their ideas (see Appendix D) There was difficulty with presenters who were clearly enthusiastic about their field of expertise but also so wrapped up in it that they were failing to engage their audience in simplified terms. If the lecture is not ‘pitched’ at the right level then the audiences rapidly lose interest. With some elements of sustainable design this is a particular risk, LCA, materials selection and analysis for example.

In the case of the ReForm seminars, where the audiences are mainly less informed undergraduate students and industry participants, the information needs to be placed in small chunks that allow for easy digestion. Another high profile speaker at ReForm 08 lost the attention some of his audience due to poor manners and a lack of professional courtesy - something all audiences take for granted. This speaker is a key writer in the field of sustainable design and strategy at an international level and yet for various reasons (outside the control of the seminar organisers) the speaker failed to gauge his audience's reactions when they clearly did not appreciate his lack of punctuality and cut across a previous speaker. This in turn meant that no matter how important his message the audience was not inclined to listen. They were perhaps biased against it from the start.

The seminar speakers if carefully chosen can provide a varied diet of ideology, experience and practical advice in a short time period. Often this knowledge would take much longer to acquire through other sources of learning.

The use of videoconferencing in this format is fraught with difficulties- technical glitches, timing issues, physical and perceived distances between audience and speaker. It does have the benefit of allowing participation from remote locations and few would doubt that it has a place as an educational technology of the future but it is still in its infancy as a communication technology. Group dynamics and rapport suffer greatly, the subtle non verbal communications between teacher and student can be lost easily and both participants have to ensure that they have patience and perseverance to get the most out of it.

The more general challenges with the seminar format include the fact that the participants can come away from a seminar day full of idealism and new enthusiasm for sustainable design. This can rapidly dissipate when they are challenged with the practical application of the theories to their every day work (as can be seen in the findings from graduate interviews in a later chapter).

It was noted at the end of the first three seminars that a need existed for a clear follow up plan for targeted work with participants after the seminar (this has been facilitated through the workshop days at NCAD and IT Sligo). Also the professionals asked for access to additional learning resources more focused on their needs as practicing designers, this was addressed partly in the development of the SDI Skillnet course.

Figure 28 : ReForm Seminar logos

In all the ReForm seminars have proven a very useful way of starting to build some local capacity and recognition for sustainable design where it previously did not exist in Ireland. Education is not only about developing students but also about forming lasting and robust networks with contacts that can assist in common goals. The industry contact that the students receive and that the organisers develop has proven invaluable in the ongoing work.

5.5 CPD (Continuing Professional Development)

5.5.1 Aims

The development of the CPD case study model aimed to show how all of the research and development to date could be animated through a singular course that took the key positive attributes of the SD learning Model (See 7). It offered an opportunity to illustrate through the applied research that Sustainable Design can be learnt through a multidisciplinary and holistic model.

5.5.2 Design Ireland Skillnet / Sustainable Design Innovation (SDI) Overview

Early in 2007 the researcher proposed to *Design Ireland Skillnet* (DIS) to develop a 'Skillnet' with sustainability focus to address the needs of practicing design professionals. *Design Ireland Skillnet*, which is an all island body, operates a series of these programmes through a national funding program that assists professional bodies in CPD (Continuing professional development). (DIS 2008; Skillsnet 2008). Primary research by Design Ireland and the researcher had shown a lack of capacity within the design specialists for design for sustainability (DfS). Professional designers from architecture, industrial design, packaging and furniture design all expressed difficulties in meeting their client's expectations and demands with respect to environmental legislation and ethical procurement.

The research involved a collaboration with three bodies to propose, seek funding for and develop a curriculum that would address these and broader issues within the design community. The three bodies involved were as follows: *Design Ireland* is tasked with linking the main professional bodies of the various design disciplines and providing CPD that is applicable to all in a multidisciplinary approach, *Cultivate Living and Learning Center* is an

NGO (Non Governmental Organisation) that specialises in delivering sustainability expertise and community level activism (Cultivate 2008). IT Carlow, through its Lifelong Learning Department (LLL) and Design Department in this case, specialises in delivering internationally accredited third and fourth level courses and qualifications and has a long history of design specialism.

5.5.3 Curriculum Development

The outline for a curriculum for this Skillnet, to be called 'Sustainable Design Innovation' (SDI), was developed by a working group from the above organisations through the winter of 2007 so as to reflect the widest possible stakeholder involvement. The outline curriculum needed to be developed in such a way as to allow 'buy in' by both IT Carlow as the validating authority and also by DIS as the part funding and promotional body. It was apparent from these negotiations that any course being developed needed to have sufficient weight and academic rigour so as to attract practicing design professionals. Also as this was to be the first course of its type in the country it was important to be able to guarantee a high quality of academic input along with an innovative approach to teaching and learning.

In April of 2008 a curriculum 'Co-Design' workshop was held to inform the development of the curriculum. Co-Design is a concept developed by Alastair Fuad-Luke which facilitates multi stakeholder involvement in the design of any product , service or system as described in (Chapman and Gant 2007). The co-design group of sixteen design, education and business professionals was brought together to develop the specifics and give feedback on the skeleton curriculum proposal. These disciplines included Graphic Design, Materials Engineering, Packaging and Brand Management, Interior Architecture, Architecture, Industrial Design, Furniture design, Textiles and Fashion and Design Education. This multidisciplinary group was facilitated for a day long workshop by Alastair Fuad-Luke and the researcher. It was felt by the researcher that in this case he was too close to the development of the curriculum to be totally impartial in the co-design process and hence the facilitation by Fuad-Luke. The mixed nature of the group allowed the development of a syllabus which gives broad sustainability theory and lifecycle thinking alongside of more specific focused specialist knowledge such as materials, legislative considerations, LCA (Lifecycle Analysis), marketing sustainability and sustainable procurement.

Key issues that were highlighted by this co-design group were as follows:

- A clear need for pragmatic strategies for implementing sustainable design into professional practice.

- Ideally the module would be validated to the highest possible level - In this case the proposal was to seek level 9 master's module accreditation at ECTS (European Credit Transfer System) level.
- A flexible delivery approach to the module so as to allow for CPD to happen alongside of daily work commitments of prospective participants/students.
- A continuous assessment model of examination - in line with designers working practice.
- A desire to link the learning from the module directly to their practice in some form.

The curriculum development team took the feedback from this co-design workshop and attempted to iterate it within the structures that exist at IT Carlow for new course development.

There were a number of opportunities which presented themselves during this development stage. IT Carlow were in a parallel process of developing two taught masters (level 9) programs through the Life Long Learning Department (LLL). These were in the areas of Technology Management and Innovation Management and would be delivered as MBA (Masters in Business Administration) offerings. It was felt by the LLL department that the SDI module would fit in well with the overall ethos of both of these masters programs as an elective module to be offered to candidates from a business, design, engineering and/or management background. The involvement of DIS allowed for a broader marketing strategy for the course and the part funding that they were offering provided candidates with an extra incentive to take the course on a subsidised basis.

5.5.4 Course Description

The course/module style follows a multidisciplinary learning approach which allows participants to develop their own philosophies around sustainable design. It is intended that they learn to innovate within their current practice and develop meaningful tools to assist them in meeting the challenges of SD. The flexible delivery over fifteen weeks allows the students to take the module part time and the PBL element will be a mentored major project related to their current work practice.

The course commenced in early October 2008 and the following outlines the key attributes of the course in terms of curriculum delivery and methodology:

- Taught and workshop contact sessions were scheduled to run every second Saturday for three hours with a break mid way - this facilitates the professionals working schedules that the students have outside of the course.
- Offline/offsite contact is maintained through *Blackboard* (a VLE-Virtual Learning Environment) used by IT Carlow - this allowed for ongoing participation in the two week intervals between contact sessions. It provides a space for any presentations, reading lists, course materials, course announcements etc. More importantly it has a facility for a virtual discussion forum for the students and course facilitators.
- The ten workshop style contact sessions were facilitated by visiting industry and education specialists who deliver both content and active learning elements to each session. These sessions were also anchored by the course facilitator Erik van Lennep and the researcher.
- The assessment method for the students involve a minimum of 80% attendance on the course along with the key deliverable which is a personal project developed with the student and mentored by the course facilitators.
- The course was limited to twenty places in line with studio based learning practice and in the interest of maintaining a high degree of contact with each student.
- A broad spread of design and business disciplines were sough through the enrolment process to ensure a multidisciplinary mix of participants.

The program content included all of the following areas:

- Introduction to Sustainable Design (SD), case studies, approaches and philosophies
- Practical sustainable design strategies for designers
- Social and environmental legislative concerns for designers
- LCA (Product Lifecycle Analysis), LCA tools, IT (Information Technology) packages, simplified applied LCA
- Social and Corporate Responsibility
- Packaging and waste considerations for designers
- Marketing sustainable design
- Communication and presentation of sustainable design and business
- Development of the SD Brief and SD Strategy
- SD Facilitation and Multidisciplinary collaboration
- Procurement and specification of materials and processes
- Sustainable Product Service Systems (SPSS)

(See Appendix C for course outline and HETAC validation information)

5.5.5 Androgogical Intents and Observations

From a teaching and learning perspective the course has been designed to engage mature and practicing professionals in sustainable design and to provide them with a foundation on which to continue to build their design practice in a more sustainable manner. It is neither possible nor desirable within a short course such as this to provide for every skill and solution that professionals such as these need in a design and business environment. It is possible however to develop their sustainable literacy and to give them tools and techniques to use in practice and to enable them to ask informed questions when dealing with complex issues. The students in this case study were from the desired mix of backgrounds - i.e. Product Design, Furniture Design, Architecture, Graphic and Packaging Design and Interior Architecture. This allowed for the multidisciplinary approach that many commentators describe as critical. The mixture of disciplines was made up of exclusively design specialism's but this was quite deliberate as a further mixture to include business and humanities type disciplines may have caused too much dilution. It was agreed that a controlled mix of design disciplines for this work was the ideal as it allowed for high level debate and less of a lead in time in terms of bringing all participants up to a similar level of prior understanding.

The profile of the first group of participants was as follows:

- Nineteen candidates took up places on the course and these were all from the East and South East of the country.
- They were of mixed ages from mid 20s to mid 50s and there were five women and fourteen men in the group.
- Some of the designers work in sole or joint practice and others in a corporate environment as in-house designers.

The Prior Knowledge (PK) study of the first round of participants to take this course indicated that they as with the SME professionals have an applied knowledge of sustainable development and had experience of dealing with issues that only pertained to their specific area of expertise. As can be seen from the figures below taken from the results of the PK study (see Appendix A for more detail).

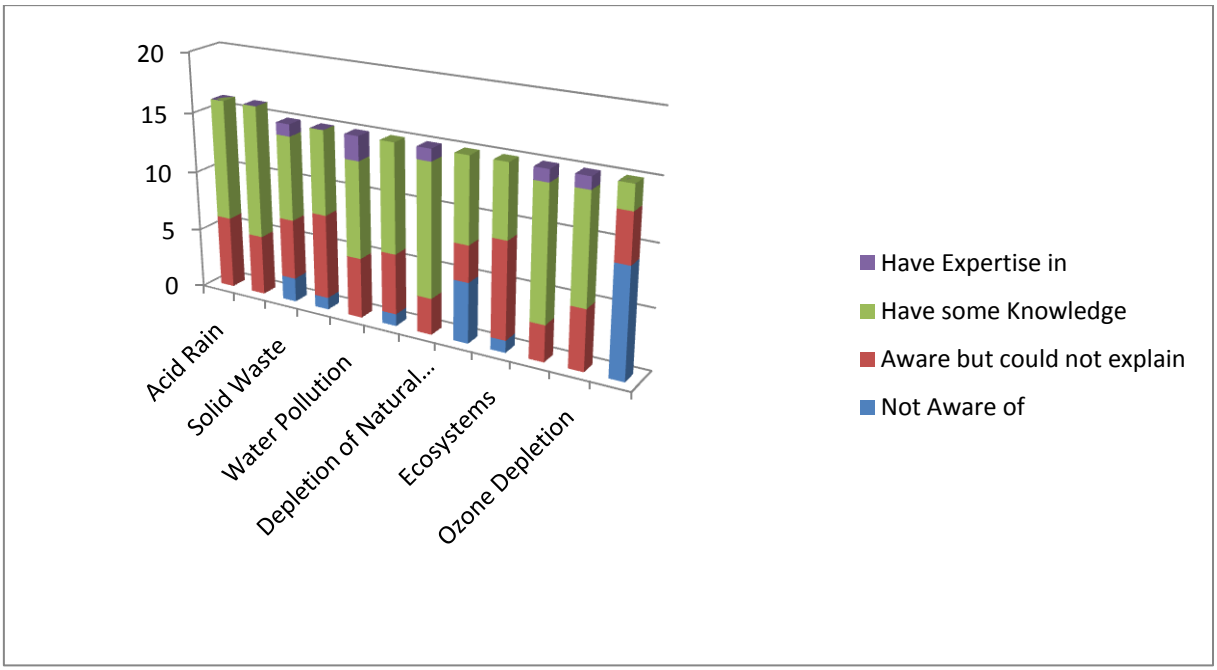


Figure 29: General Environmental Issues

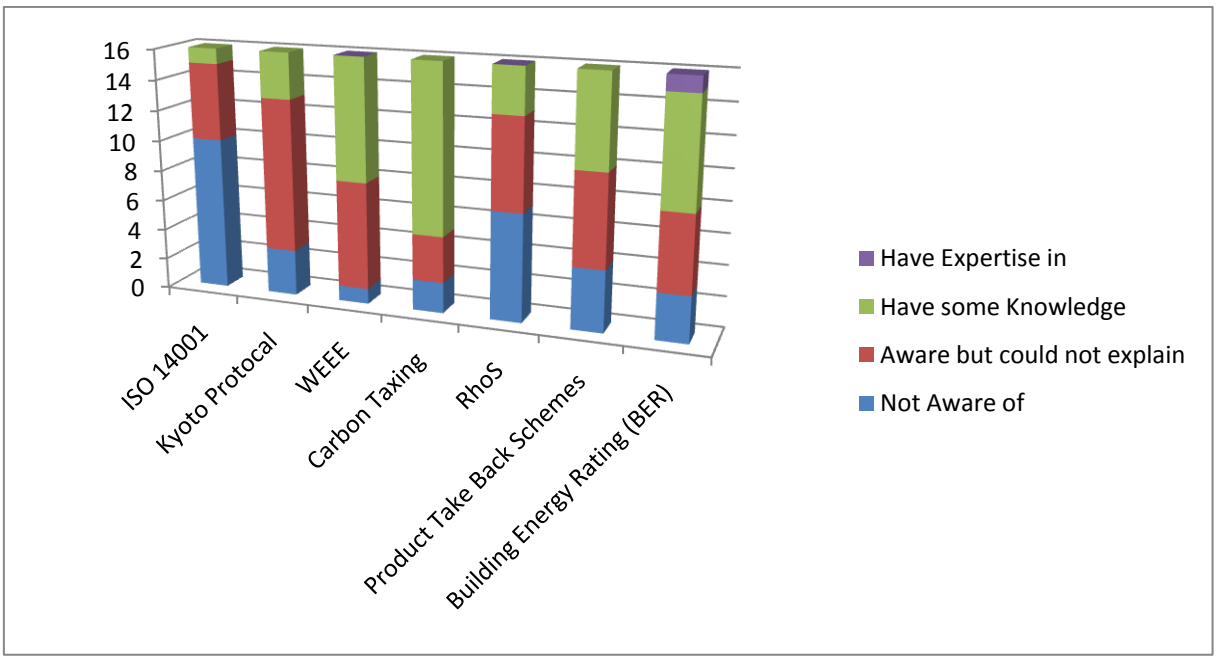


Figure 30: Environmental Legislation Policy and Standards

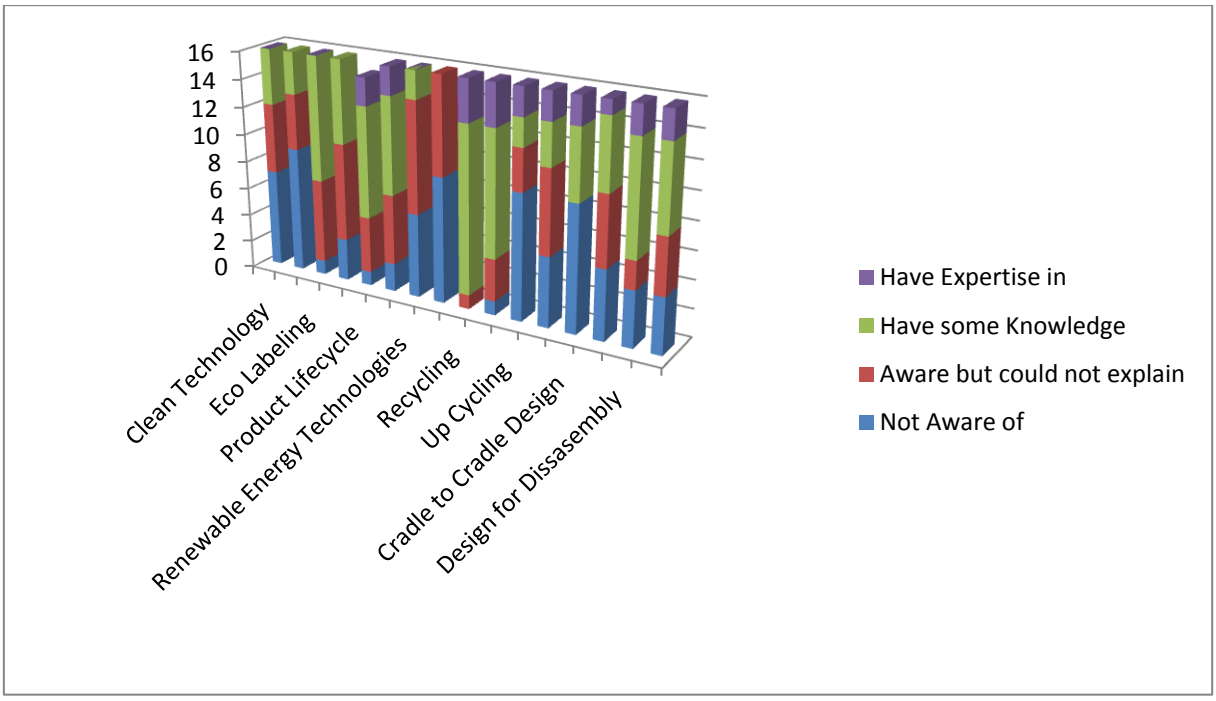


Figure 31: Environmental Tools, Technologies and Approaches

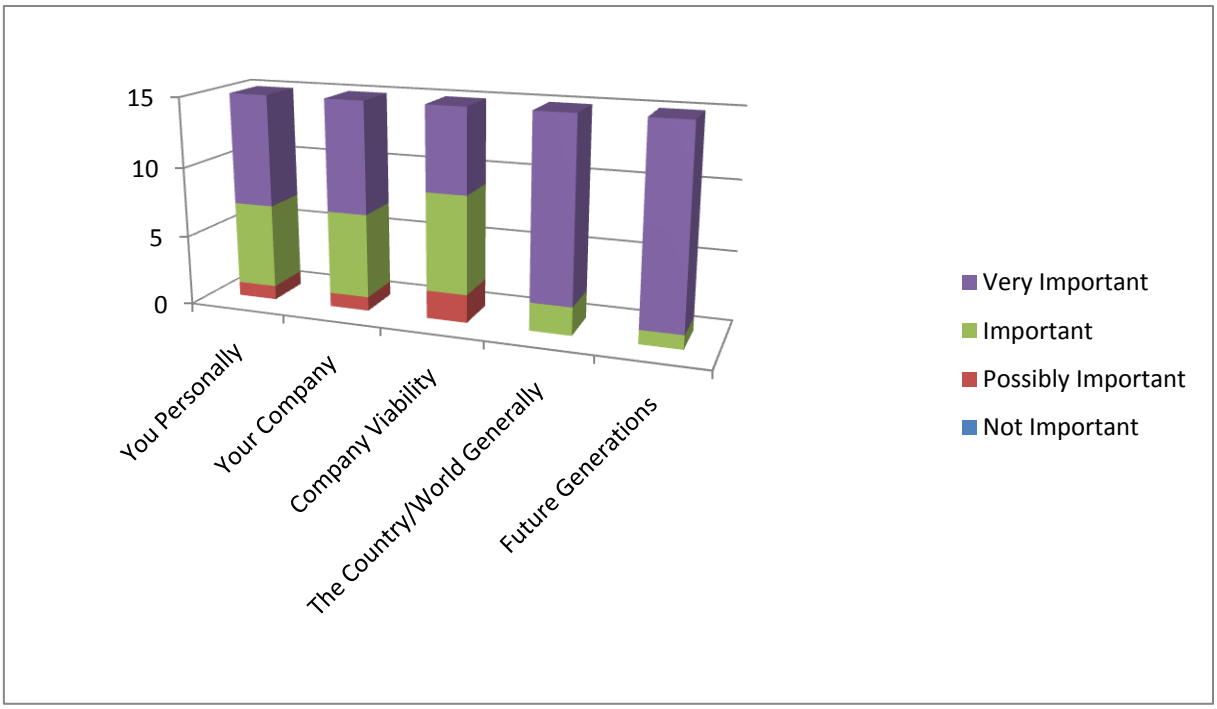


Figure 32: Rating the Importance of SD and Manufacture

There are some overarching observations that could be taken from the survey. It would seem that most participants (while being practicing professionals) have either humility or a genuine lack of knowledge around environmental policy and legislation. It was surprising, for example, that twelve out of the sixteen had only basic knowledge of the Kyoto Protocol, and could not explain it, despite its wide discussion in the press over recent years. Significantly

however in this section they did as a majority express having some knowledge on carbon taxing. This would suggest that the terminology needed is much more subtle than perhaps with undergraduate students. Carbon taxing is an issue that will directly affect their businesses and it has been highly topical in the Irish and International context over the past year or so.

From the start it was clear that the participants were enthusiastic and committed to their learning on the course. There were of course varying perspectives and levels of both design and business literacy and of sustainable literacy. The fact that they are all mature students and more importantly that they are practicing professionals meant that their expectations of what the course could and would deliver were more realistic. Post graduate students by default are often more driven and focused than undergraduate students. There is a clear distinction between experienced and less experienced students that perhaps is related back to Knowles' Andragogy v Pedagogy debate described previously and in (Jarvis and Griffin 2003). These older mature practicing professionals bring current thinking, sharp analysis and a no nonsense approach to education that is often lacking in undergraduate education.

The course was designed to develop the participant's knowledge, skills and competencies under the following headings:

- Introduction to sustainable design
- Practical sustainable design innovation strategies
- Social and environmental legislative considerations
- Lifecycle thinking, simplified LCA (Lifecycle Analysis)
- Materials selection and procurement
- Corporate and social responsibility
- Packaging and waste considerations for designers and business
- Marketing sustainable design
- Sustainable design for competitive advantage
- Applied research project

These headings provided the basic skeleton for the course structure over the 10 direct contact sessions. These sessions were complimented by reflective periods discussion sessions and active work sessions during which the participants were encouraged to engage with each other and the facilitators (as per Kolb's Learning Cycle) i.e. Observation and reflection, generalisation and abstract conceptualisation, active experimentation and concrete experience.

Throughout the course a high level of ‘online’ time was accommodated through facilitation and through the use of the *Blackboard* (Blackboard 2009). This tool allowed the course to document the discussions that students were having between the contact sessions. It was important that this was not the only format of discussion as it has been observed that different learners engage and learn in varying manners (Felder and Silverman 1988). It was noted that about 20% of the participants did not regularly engage in the use of *Blackboard*. This was no doubt due to a number of factors - lack of free time to engage online with the course, confidence issues around expressing opinion and comment in a virtual space, initial technological challenges with the virtual format.

The remaining 80% of the participants developed a dynamic that far exceeded the expectations of the course facilitators; they showed ability to self direct their learning. As the emphasis of the course changed from session to session the online discussions could be seen to absorb the issues raised, contextualise them and more importantly elaborate on them. It is always fascinating as a facilitator to see some of the directions that a group can choose to travel when given the space and facility to develop. As facilitators the learning was of course mutual. There were elements to the course that were new to us and the visiting expert lecturers (while all being professional contacts previously) gave us the opportunity once again to re-evaluate our own understanding of sustainable design. The fact that the participants are all practicing professionals provided the facilitators and many of the guest lecturers with a unique and practical application of much of the SD theory. This can be difficult to gain when a facilitator or expert becomes overly specialist- often one works exclusively in education or in a consultancy role without the opportunity to apply the theory.

One of the real challenges that is apparent from this case study is the development of a long term strategy for delivering the high level of contact with the participants and the expert engagement on the course. There is a real risk that the first year of the program would provide close to the ideal in terms of educational approach but that in time the enthusiasm of the facilitators and the university would wane. Some continuing work needs to be done in terms of maintaining the androgogical intent of this course. The balance of expert speakers, the ability to adjust the content to suit the learner group and the ability to maintain the standard over time are just as important factors as the other elements described above.

5.5.6 Course Outcomes

The first year of the course ran between October 2008 and March 2009 and so the long term outcomes of the program are difficult to assess in terms of effectiveness. Despite this it was

possible to garner sufficient feedback from the nineteen participants in terms of their impressions of the course and its usefulness to their personal and professional development. In addition to this Design Ireland completed an independent feedback study midway through the program. The participants and the findings of this were positive in the main as can be seen in (Appendix D).

The course participants all developed a personal project which related to their professional practice and attempted to embody the learning throughout the course. The projects were varied in topic and showed the diversity of opportunity for designers from many design disciplines to use sustainable design as a tool for innovation.

The following projects were undertaken in the 2008/09 course.

- Recyclable toothbrushes
- Medical device design (Endoscopy LCA and redesign for recycling and EoL disposal)
- Green rating within Graphic Design
- Replay – Don't throw away (Kids toys)
- Education campaign for ILCB (Irish Life) staff
- Sustainable options for apartments
- Outdoor smoking area and roof garden
- Sustainable office
- Passive/eco-house design
- Jigsaw table
- Sustainable wastewater treatment solutions
- Beach space (temporary retreat unit)
- Sustainable kitchen solutions
- Greening the 10 year office
- Sustainable package design (MP3 accessory packaging)
- SD resource kit for industrial design consultancy
- Living paper (Graphic Design)
- Transporting ideas (Office Furniture Design)
- Organic viniculture at a glance (Web Design)

The outcomes from all the participants were very encouraging as they demonstrated that professionals can re-adjust their professional practice and thinking to include sustainable design thinking when a course such as this gives them the knowledge and skills to do so.

The students all performed highly in terms of assessment with the average grades being awarded at B and B+ levels with the lowest grades at C+. This supports the observed high level of ability and engagement with the course.

Professionals in the main are looking for pragmatic tools and philosophies that sit comfortably within their personal and professional experience. These very qualities can also be a limitation to their development in sustainable design terms as this field often requires non standard thinking. Some of the participants in this case study clearly demonstrated a frustration with ideology and philosophy at the outset. There is a responsibility on the facilitators to constantly justify and contextualise these elements in the course.

There was a concerted effort made to introduce conflicting perspectives on sustainability in the delivery of the taught elements of the course. This was done by staging the content of the visiting lecturers. One week the lecture would be more idealistic in tone and the following would be pragmatic and skills based. The nature of the visiting lecture model enables the participants to align themselves more closely with one or other approach and to question and critique each approach as the course proceeds.

All nineteen of the participants who took the course also completed it and this has allowed the first group to form a network that they can continue to develop. There has been a suggestion from the participants themselves that they would like to gather again in six to eight months time to review their learning and to look at how their personal projects have developed from the implementation stage that they proposed at the assessment stage.

Further analysis of the feedback and conclusion from the first year of running of this module are to be found in the Conclusions section of the research.

5.6 Follow on Study of Students

5.6.1 Graduates

For the purposes of assessing the effectiveness of the learning strategies outlined previously in 4.4.3 and 4.4.4, four graduates from one of the classes described that were involved with this study were interviewed. The interview process in this case attempted to give a qualitative sample of graduates' current experiences.

These interviews examined their current work in industry and the attitudes of their employers towards sustainable development and design. The graduates work in four radically different areas of industry and reflect the varied fields that design graduates find work in.

Table 3: Interview responses from graduate ID students outlines the responses from those interviews (for details of the full list of questions asked refer to Appendix B).

The qualitative interviews of the graduates from IT Carlow concluded the following:

- The graduates are influenced greatly by the constraints of their specific employers. Their ability to apply their sustainable design skills and competencies can be greatly limited or enhanced depending on the focus of the company.
- There is an obvious need for company 'buy in' with respect to sustainable design and development. Graduates will not change the culture of a business on their own.
- The sustainable design education that the students engaged with has in the main influenced their employers and the practice of the teams that they work with. Often this is in small incremental ways but as the graduate's progress their influence will grow also.
- The confidence and seniority of these graduates is indicative of any new graduates attempting to create a niche within a company. They need time to grow into the position and not all companies (understandably) can entrust them with strategic decision making at such an early stage.
- All four of the interviewees had made significant impact within their companies and all had attempted to implement some form of sustainable design.

Graduate Interview Feedback (4 Graduates from ID Class of 2006 at IT Carlow)				
Interview Questions	**Design Engineer, (Agricultural machinery)**	**In House Designer, (Medical training devices)**	**3D Visualisation Designer, (Construction engineering)**	**Product Designer (Passive ventilation systems for architectural use)**
Did the specifics of your HDP (honours degree project) /portfolio influence your employment?	Yes, both had an influence. They were very impressed with my portfolio and the relevance of the project to my line of work also helped me.	Just the fact that I had worked on a live project for my HDP was key.	Yes, the fact that I had a portfolio really impressed them, there was that wow factor, also the detail of the HDP work was above their expectations.	Yes, very much so, more when I was integrated into the team to assess my skills.
What is your current thinking/understanding about sustainable design	Feel that it is important but I would be more realistic about what I can influence.	It was what I wrote my thesis on and I still think about it but have no opportunity to put it into practice.	More realistic about what can be achieved, decisions made at the start of a project make a big difference.	More important than ever. It is our companies core business and clients come to us for our expertise.
Does the fact that you studied SD as part of you course influence your decision making in your current work?	Yes, it is something I think about but find difficult to implement.	Yes and No.	Yes, it allows me to communicate with the engineers and architects in a more confident and probing manner.	Yes, we were given a broader view of SD than many of my colleagues who never touched on it in their education. That helps a lot.
Has your perspective changed with time? (the idealism of being a student V the realism of employment and dealing with clients/employer)	As a student you are more naïve about what you can produce, the realism of the working world makes you less idealistic.	University does not prepare you for time lines and the rapid pace of development in industry.	Yes, but the company have a positive approach to nurturing new employees.	Industry is difficult, you become very specialist and it can be difficult to use all your creative skills. Being a student allowed for it all to be explored.

Interview Questions (Cont.)	Design Engineer, (Agricultural machinery)	In House Designer, (Medical training devices)	3D Visualisation Designer, (Construction engineering)	Product Designer (Passive ventilation systems for architectural use)
Can you describe the attitude of your employer towards sustainability, if any?	It is not explicitly discussed except from an economic and health and safety point of view.	None, it does not even get discussed.	Very positive, at the top of their public profile and at the forefront of developing new strategies and guidelines for construction industry globally.	Practical and specialist. They have product lines that sell as sustainable alternative competitors. They see it as core business but I feel it could be marketed better .
Is there a notion of Product Lifecycle Thinking (LCT) in the design work that you are involved with?	Yes, the service that the company provides to customers is important and the product has an extended life as a result.	Yes, the products get serviced and have upgrade options for our customers.	Yes, but more in terms of energy usage of facilities and embodied energy in materials etc.	Yes, to a degree, modularity and repair are important but other opportunities are lost , reclaim of materials etc.
How does your company approach New Product Development (NPD)?	Modularity for ease of service and customer needs are important	The current product has had a lot more investment in terms of research and attempting to make it multifunctional.	In the traditional large project design sense, multidisciplinary teams, briefings etc.	It has a NPD team that works on this but they are a bit closed in their interaction with other teams.
Is local manufacture a priority for your company Is local procurement an issue (for components or services?	Yes, the family are still very involved and are keen for various reasons to keep manufacture and procurement local.	Yes, local manufacture helps us keep an eye on quality and is easier to manage for us.	Yes ,even though we are a global player local procurement and labour are important as they help with quality control.	Yes, all components and manufacture is done within a 50 mile radius. We don't have any great advantage in outsourcing and our clients look for local manufacture.
Is sustainability a priority in your companies work?	Not explicitly. The company philosophy is more about end- product quality and efficiency.	No.	Yes, at the top of the agenda going forward.	Yes, most definitely.

Interview Questions (Cont.)	**Design Engineer, (Agricultural machinery)**	**In House Designer, (Medical training devices)**	**3D Visualisation Designer, (Construction engineering)**	**Product Designer (Passive ventilation systems for architectural use)**
Is sustainability identified as a concern for your customers?	It is a growing concern but not top of the list.	No.	Yes, more and more clients are expecting sustainable solutions .	Yes, most of our clients are architects or engineers who specifically spec. for sustainability reasons.
Do you or your company see sustainability as a tool for commercial advantage?	Not at present.	No.	Yes, it is one of the reasons the company is a world leader in the field of construction.	Yes, much more in the last 4-5 years than previously, there is a clear demand for it now.

Table 3: Interview responses from graduate ID students

6 Educational Strategies and Models for Sustainable Design Education

6.1 Strategy

This research has developed a series of key strategies for sustainable design and multidisciplinary sustainability education that have been informed largely by four areas:

- Current best practice with respect to design education.
- Benchmarking and analysis of other sustainable design teaching models.
- A clear customisation of the teaching delivery, learning and assessment methods to suit the particular participants in each case.
- A consideration for the past, current and possible future issues that inform sustainable development.

There has been some discussion about whether the work undertaken has been a development of new models or just a modification of existing models of design education. The research has in fact developed both. It can be difficult to parse out specifically where new methods have been found and where old models have been tweaked and modified. What is clear however is that specific androgogical aims have been proven and the research clearly shows how sustainable design education differs in some elements from traditional design education.

The research has developed both some new and modified models while in tandem it has organised these models so as to be implemented within different aspects of the higher education and professional realm.

The models developed here include the following:

- An Honours Degree Project model (emphasising on SD) see 4.4.4
- A CPD Model (for the Sustainable Design Innovation course) see 5.5
- A Seminar model (through *ReForm*) for multidisciplinary seminars. see 5.4
- An SME Workshop model (through Winnovate) see 4.7
- An undergraduate Multidisciplinary project format (Through the MDPs) see 5.2

The strategy includes the blending of various teaching and learning approaches to form an overarching approach to the teaching and facilitation of sustainable design. In the context of this research it has been possible to look at existing case studies of design education from a sample of national and international institutes and universities (as outlined in the literature review 2.3). The sample of case studies has attempted to give an overview of how product

and industrial design has been taught to date and how elements of sustainability have been introduced into the curriculum over time. It also gives an overview of how other disciplines within the engineering field are implementing sustainable development in to their curricula.

Some of the courses (such as the Bootweek in TU Delft 5.3) have sustainability thinking embedded as a core philosophy within the overall ethos of the course, faculty and even institution- in these instances it has been possible to see the benefits of an institution wide approach to sustainability in education. These courses find it much easier to implement multidisciplinary methodologies as they are not as pressured to find allies within parallel disciplines. They can rely on support from a resource and administrative point of view. The institute or university structures are often set up in such a way as to support initiatives and innovative approaches to teaching and learning of sustainable development.

It should be noted that the courses, modules and initiatives developed as part of this research have been done within the confines of an institute (IT Carlow) that has very little commitment to sustainable development. In broader terms there is no higher level management ‘buy in’ and there has not been any attempt on the part of the institute to develop an institutional sustainable development strategy. There has been support for the research from Head of Department and Head of School Level, however institutional reform was beyond the scope of the research. This is pertinent in the context of what is practical to achieve in a scalable sense within other educational establishments. It is possible through the energies and commitment of a small group to implement educational change without full institutional ‘buy in’. Of course it would be desirable to have a broader appeal and to include all stakeholders in a wider education context however this can be an all consuming process.

It was decided early on in the research that institutional change was a secondary goal and that the primary focus should be on the development of scalable strategies towards sustainable design education. It is hoped that these strategies would not only be scalable but also transferable to other educational environments.

6.1.1 Strategic Considerations

From a strategic perspective there are some constraints that should be considered when attempting to implement a sustainable design element to any curriculum. These include:

- *The human resource capabilities* - are the teaching staff sufficiently versed in SD and is their expertise up to date with current trends, technologies, materials and approaches?
- *Diversity of opinion* - the learners and the facilitators must open to multiple perspectives and a diversity of opinion and expertise. This is an essential element to ensure robust philosophy.
- *Student commitment* - not all students will see the immediate relevance of an SD intervention to their course of study, the facilitators job in this case is to animate the area for them and to challenge further those who are interested already
- *Prior knowledge* - it is important to pitch the level of any course, project or learning method at the level appropriate to the learner. Understanding their prior knowledge is therefore important.
- *Style of delivery* - the format and style of the learning environment and delivery are important to sustainable design. Studio based, high levels of discussion, group work and a self learning, reflective approach all need to be facilitated.
- *Assessment mode* - the learner's knowledge is less critical than their ability to utilise multiple sources and strategies around sustainable design, the assessment methodology should reflect this, project assessment, peer critique and continuous assessment should all be considered.
- *Resources* - the availability of resources is a factor in curriculum delivery, small class sizes, mentoring (high facilitator/student contact ratios), studio based facilities and open access to IT and library reading resources are all critical.
- *Institutional support* - not critical but desirable in the context of a broader environment for sustainable development learning.
- *External environment* - the changing nature of the marketplace, the social norms and the global environmental and economic realities all need to be re-evaluated on an ongoing basis.

Case studies such as the SDI and ReForm initiatives showed clear benefit in utilising local expertise and contacts to deliver the programs. There is a temptation to always look outside the country for experts in the particular specialist areas and, in fact in some cases, this is essential. It is equally important to develop local solutions and to build a community of

expertise at a local level. In order to do this sometimes the experts need to be given the platform to work from. When it comes to strategic institutional change it would seem that ownership by multiple stakeholders must be a determining factor, one or two individuals can not on their own support and deliver an institutional commitment to sustainable development.

6.1.2 Androgogical Principles

The essential androgogies that the methodology developed in this research are based on are best expressed through Kolbs learning Cycle (Kolb 1984) and through Felder and Silverman's (Felder and Silverman 1988) models which have been modified and elaborated on to produce the proposed sustainable design learning model (see Figure 35).

Once again it is important to differentiate andragogy (the teaching and learning of adults) with that described as pedagogy (the teaching and learning of younger students and children). This differentiation is subtle but important in the context of sustainable design education. The two terms are often interchangeable however andragogy does emphasise a more self directed, self evaluated and facilitated mode of education on the part of the adult student. The adult student in the case of the CPD and SME case studies are also taken to be a students with some experience of industry. This is different to the undergraduate student who while still an adult is less experienced and so has a different context for learning. The research has shown clearly that treating it as an adult learning environment develops a more holistic understanding of sustainability and a more enabling approach to the application of the understanding in the real world.

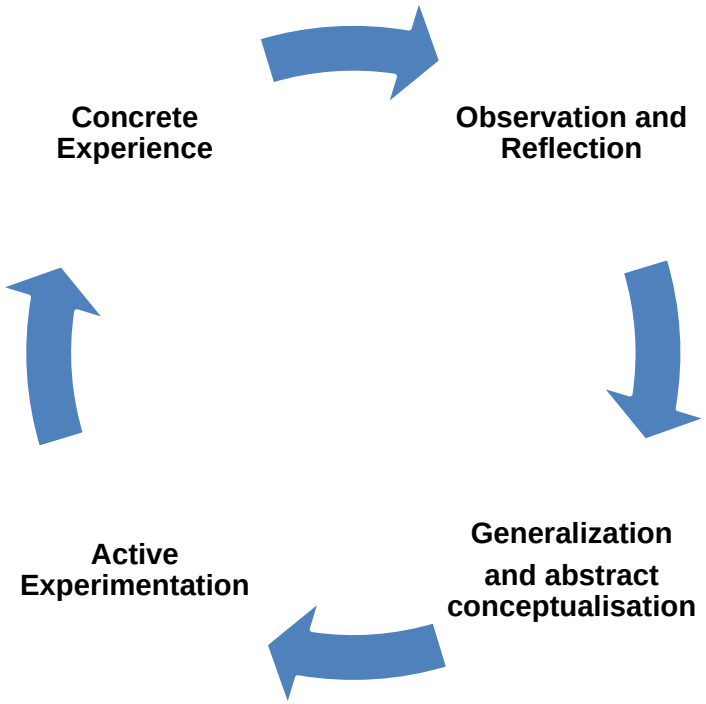


Figure 34: Kolbs Learning Cycle

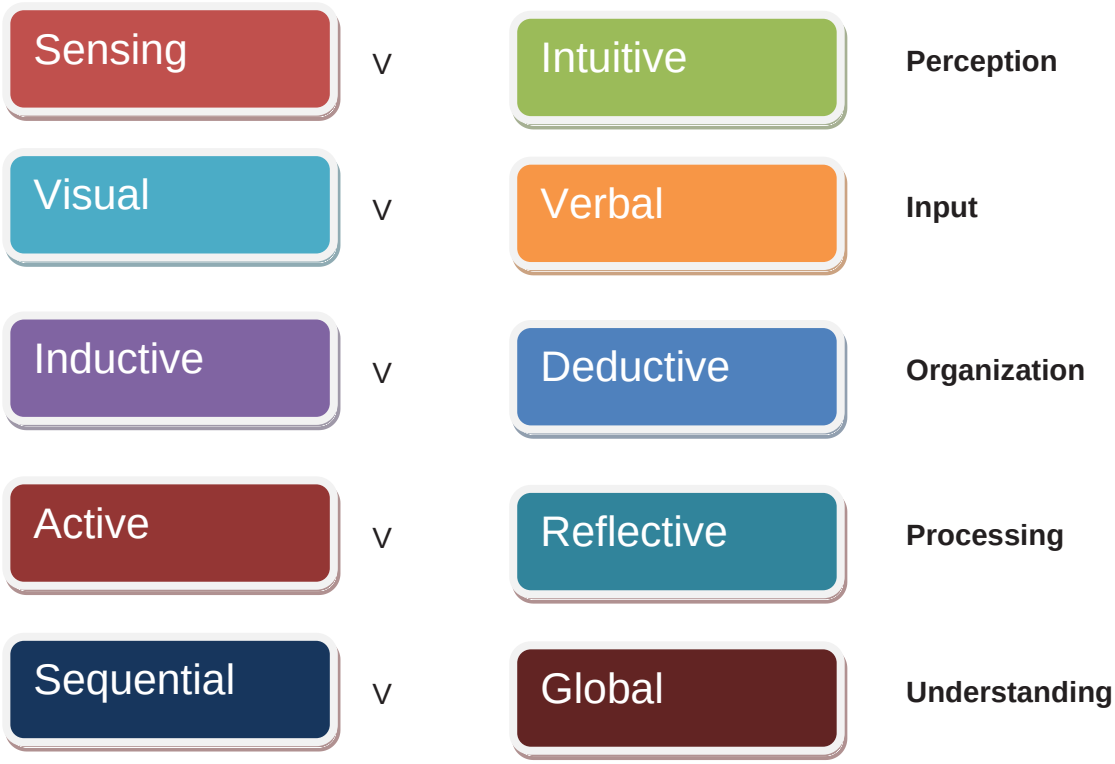


Figure 33: Felder-Silverman model of learning dimensions

The Felder-Silverman model of learning dimensions (as illustrated in Figure 33) shows how the learner progressively learns but in nuanced combinations of dimensions. This model was particularly useful in the context of the overall thesis as it reflects some of the critical elements of learning that were explored as effective for specific sustainable design learning. With designers the perception of the subject matter is often both a sensing of the appropriate focus and an intuative response to the initial elements required by the design. The intuative elements are normally more astute as design maturity developes. The input dimension does depend on the subject matter being addressed. Visual input has a very powerfull context for designers in general and the processing of visual input does happen in a sophisticated manner with great degrees of detail and nuance able to be communicated also through visual output. A mixture of the verbal and visual input was chosen with the SDI students for example, as an appropriate measure .It was observed that professionals had a greater level of concentration and an ability to spend a number of hours with a complex subject. The undergraduate students on the other hand have less developed levels of concentration and a bias towards the visual, in this case is preferable.

Of course, some learners do not automatically fit in to the categories and it is important that the facilitator/animator/lecturer allows for both types of learning dimension. The offline reading or viewing is critical in this context. Much of the formall curicula that were used in the case studies are provided merely as a foundation for the student to learn. They then, through their own self directed research and interest, fill out their learning with a wide variety of sustainability information. Ultimately it is the combination of the formall, prescribed and applied learning with the informal, exploritory and creative learning that developes a robust and durable basis for sustainable design.

7 The Sustainable Design Learning Model

The SD Learning Model is intended as a distillation of the research on sustainable design education. The analogy of the acorn and an oak tree is offered as it best illustrates the education process and has opportunity to show the complexities of SD learning as the research has observed. The growing of an oak tree requires favourable environmental conditions, the right mix of nutrients and, most importantly, time. Over its' lifetime the tree is subject to many changes in seasons, weather and external influences beyond its control. It is differentiated from other oak trees by the locally specific growing conditions, soil type, pollution, other flora and fauna, damage incurred etc. Finally the mature oak tree provides a self-contained system for self and cross-fertilisation, nourishment of new seedlings and a habitat for a whole range of other species.

This research has only been able to look at this process over a five year period and much of the latter stages of the model would need further study to gauge its effects into the longer term. It has been suggested anecdotally by professionals that students do not reach their full potential until a number of years after they graduate or complete a course. Their contribution to society and the environment may not start to materialise until they mature in industry or in further study.

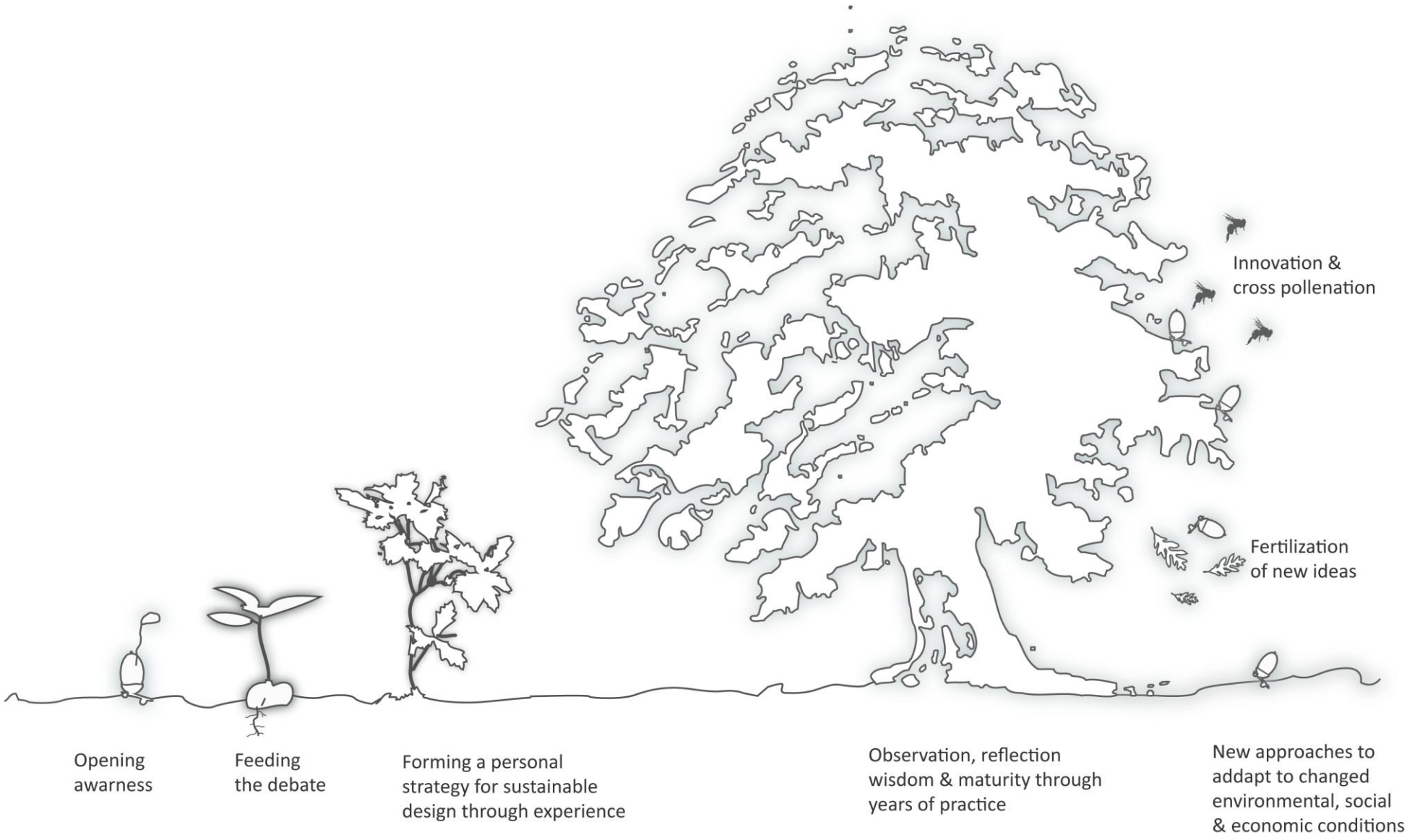


Figure 35: Sustainable design learning model -as proposed by researcher - (de Eyto 2008).

7.1 Opening Awareness (The Acorn)

The aim from the start of any of the initiatives outlined above was to open up the awareness of the students to the complex nature of sustainable development and how this starts to relate to their area of education i.e. Design. (In this case the 'student' refers to not just the undergraduate student but also the SME professional, the professional designer in the CPD program and often, but not always, the lecturer).

Initially when presented with this complexity there is a risk of overwhelming the student with global issues of poverty, resource depletion, environmental crisis and economic uncertainty. For many students this is the first time they have been encouraged to think about such issues in a formal learning environment. Of course each student brings to the process their own experiences and personal philosophies and it is critical that they be allowed to develop their interest in an academic forum as well as in a personal capacity. It is important from very early on to differentiate personal passions from professional interest. Sustainability has a tendency to spark strong reactions either in terms of extreme points of view and often crisis of conscience. In some cases the student will be cynical and even disinterested in the content but in the main this research has found these students to be in the minority. Students who do engage tend to re-look at their design philosophy as it has developed to that point.

With undergraduate students this is less of a problem as their understanding of design and its application to society is less mature. They have only started to appreciate the complexity of design by the time they are in their third or fourth years of a program. If the educator manages to engage these students prior to this phase - in the second or third year of a full time program for instance - by beginning to open their awareness to sustainability and how it impacts on design. It is then clear that these students take on the literacy and use it as one element of their skillset in their broader design education.

With SME professionals there would seem to be a slight variation. They are often trying to open their own awareness to sustainability from a commercial perspective. They are keen to 'run before they can walk' in a design sense, i.e. they want to implement rapid changes to their practice for commercial survival rather than to develop their understanding in a strategic manner. It can be more difficult to engage these individuals in terms of opening awareness as they come to the education process with much more industry experience. They also normally bring many more prejudices and strong opinions. This can be channelled but it does require a different teaching and learning approach.

The design professionals seem to have the ability to develop awareness between the two other groups. They have the pragmatic approach and wisdom of industry through maturity and experience. They also seem to have latent idealism (perhaps from their student days) and the ability to set aside their pre-conceived notions on how industry and society must function in order to explore new ways of thinking. As with any group it can be unwise to generalise too much but the observations and feedback from the SDI course (see 5.5) would suggest that this group do have the ability to separate pragmatism from idealism.

This phase of opening awareness is critical as it is a pre-cursor to any meaningful exploration of sustainability. Without this awareness the learner tends to develop naive design work that reflects only their immediate opinion on a sustainability topic or even a passing fad. Much of the commercial world is guilty of this limitation when it comes to sustainable design and eco-design especially. Awareness encourages the student to see things from a broader perspective and to develop their basic sustainable literacy so as to form the common language by which they can communicate with others. From a design perspective it is another version of that essential research phase of any project. It begins to inform and contextualise the design brief and give it some parameters. More importantly, it offers the first creative opportunities and allows the student to start to see lateral strands that could be developed. The acorn is analogous to this process as it requires the right DNA and growing conditions to germinate successfully. Unsuitable seeds are usually self de-selected at this early stage.

7.2 Feeding the Debate (The Germinating Seedling)

The next progression in the methodology as it developed during the research was to actively feed the debate around the specific sustainability topic or the design. Students at all levels have the capacity to inform themselves through peer to peer debate, discussion and through structured group work. The challenge here is providing the right forum and variety for such discourse. The forum or method used can vary according to the nature of the group and or the course. It is a difficult aspect to develop if the student is intent on learning alone. Some of the techniques used in the research included: group discussion forums, formal debate, online discussion forums, studio tutorials in group or one to one and finally seminar workshops. The approach used with the undergraduate course work was to structure a mix of formal and informal debate that challenged the perceptions of the students.

In the case of the project based work that the students developed they were asked to give formal stand-up presentations of the various phases of their work to visualise and verbalise their research findings. This gives the opportunity to their peers in a studio environment to

critique their work. The lecturer's job in this context is to act as both facilitator and as a counter perspective (if the class do not rise to the challenge). It is critical that this process be managed closely as unstructured negative feedback can cause adverse reactions in the student.

One experimental method used with a second year group of Industrial Design Students at IT Carlow used the formal debate mechanism. Two separate groups were formed as part of the Design and Contemporary Culture Module to debate *The human contribution to global warming* as an issue. The two part exercise involved showing the two groups a selection of opposing perspectives on global warming - video footage of *An Inconvenient Truth* (Guggenheim 2006) on one side and *The Great Global Warming Swindle (Durkin 2007)* on the other. They were then given time to do further research and to formulate their arguments. The debate proper was held the following week with each side debating as per specific debating guidelines. The final outcome was an open forum debate in which all the students in the class made observations on the debating points and on the two perspectives. The important learning points explored here were the ability of the students to make rational argument supported by relevant evidence and to debate with an opposing perspective on factual terms. The actual opinion of the students, while interesting to the researcher, was not relevant as here we were keen to explore their ability to take a stance regardless of their personal point of view. This skill should allow students to see design rationale from various perspectives and not just from a singular personal one.

In the case of the SDI program for instance the format was modified to account for their distance learning between classes. The use of *Blackboard* (the VLE (Virtual Learning Environment) as outlined in 5.5) was critical in this context and the use of the online discussion forums allows for some of the class to explore practical and philosophical threads of discussion in a recorded manner. The VLE allows for a considered commentary space which encourages students to express their views, experiences and findings with one another. The VLE discussion board also allows the participants to have a didactic forum in which to express their views in an alternative manner to open face to face discussion. Some students (even professionals in this case) show a greater willingness to engage with discussion in this 'remote' manner. The written word can be clearer when consideration is given over time to the sentiment one is wishing to express and hence this version of a discussion forum is valuable. On the other hand the SDI course has shown that not all students will have the time or motivation to express themselves in a virtual forum. If they have a busy work schedule, or are uncomfortable communicating in a virtual environment, if they have limited online access from home or work these restrict their interaction in the

debate. It is important also to vary the approach to feeding debate. The facilitator or lecturer needs to be able to effectively use counter argument, a 'devil's advocate' approach, satire, conflicting expertise and humour as a means for promoting discussion. Satire and humour are suggested since the academic side of sustainable development often is extremely serious and can be almost dogmatic in its communication. Righteous perspective and extreme approaches can be difficult to engage many students with. This researcher found that humour and satire (often at one's own expense) is very useful in terms of engaging the student and developing empathy with a group. Within the proposed model the germination of the seedling requires stimulus that are subtle, in the case of the oak seedling, gravity, light, fertile soil, warmth and water- in the case of the sustainable design student, discourse, challenge, and the ability to access information and to be able to process this information in a critical manner.

7.3 Forming Pragmatic Strategy Through Experience (The Sapling)

Knowledge is fertilizer for Awareness- (Leo Jansen EESD08)

In the middle stages of the learning (or growing) process the student is now working on a live or conceptual design project. They have moved from the generalisation and abstract conceptualisation, as Kolb would describe it, and on to the active experimentation stage. They are attempting to contextualise their knowledge and opinion in to a workable strategy that can be applied to the traditional design process as described in Figure 36.

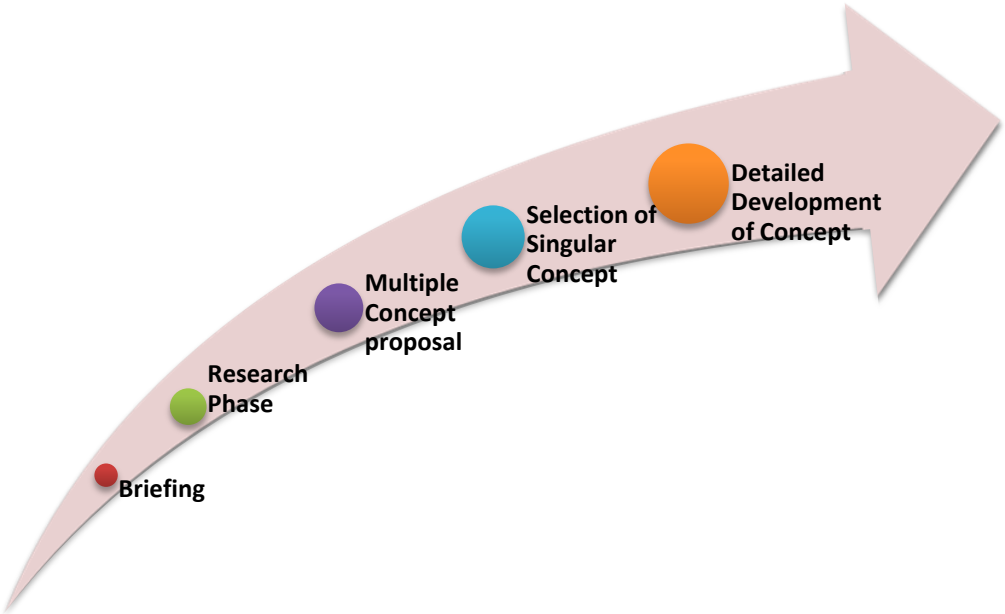


Figure 36: A simplified design process (as defined by the researcher)

With respect to experimenting with sustainable design strategy they need here to develop a pragmatic strategy that allows them to take the broad concepts they have come to understand and to apply them to a challenge or issue. Often this is done through the vehicle of a concept development phase (as described above in Figure 36). However in some cases it may be the modification of a case study strategy or previous experience that they may have had. For example in the case of the SDI students they were asked to develop personal projects that relate to their design practice. Some students have chosen not to take on a traditional design of a product or service system. Instead they have chosen to develop a company strategy or a set of guidelines for procurement or a communication tool for communicating sustainability to their company. There are some very important stages in the design process that allow for a holistic solution to emerge. These include the development of the brief, the research, (Figure 37) the lateral/divergent thinking idea generation activities. It is at these stages in the design process that the use of techniques such as LCT (Lifecycle Thinking), LCA (Lifecycle Assessment), C to C (Cradle to Cradle thinking) or Back Casting models can prove to be extremely useful.

Experience is sustainable design of course is similar to all disciplines, it comes with practice, learning by doing and reviewing, learning from mistakes and constantly re-evaluating ones process. This can be a difficult concept to animate with undergraduate students, however the three or four year process that they complete in their degree program can give them the space to develop this design maturity at least to a level that makes them employable and adaptable.

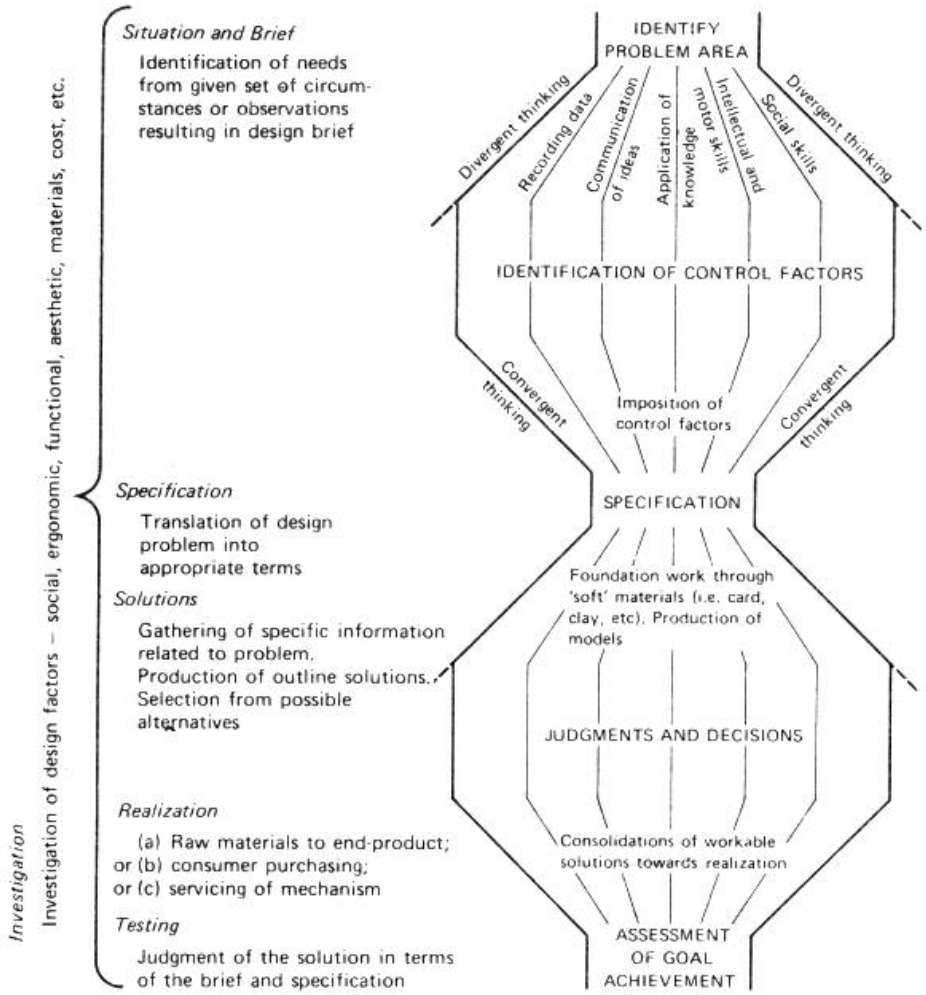


Figure 37: Divergent thinking, development of the brief and identification of the problem area through research

- All are important aspects of the 'sapling' stage of development as in (Arnold and Eggelston 1971)-

The important element of this stage in the learner's development is that they are given the space and time to develop their sustainable design abilities. They need time to learn the new approaches and like with any skills they need time to perfect them so as they become an integral part of their skill set. The challenge for industry practitioners is in creating this space for new learning and experimentation. The SME workshops and the SDI module showed how participants can take time out from their busy schedule and apply their considerable experience to a new way of thinking. Many of the respondents from the feedback on these case studies made this point that the format gave them the time to dedicate to their professional development.

The ‘sapling’ phase of this analogy is dependent on many variables, environment, weather conditions, other competition, some luck and a constant supply of nutrients. The learner similarly has the possibility to grow in to a sustainable designer if they use the environment and take the opportunities that are clearly there to develop a sustainable design strategy in the university and the professional workplace.

7.4 Observation, Reflection, Wisdom and Maturity (The Oak Tree)

The growing process that is being described here is not necessarily a chronologically linear process as one might assume. In fact it does seem to allow for elements of new growth (or mutation) at any stage. The student’s participation in the learning process is critical here. Students who do not take the opportunity to reflect on their learning for example do not necessarily benefit from new creatively generated understanding of sustainability. The process of reflection therefore needs to be facilitated at all stages. The wisdom and maturity develops only when the learner goes through the process a number of times. As is typically described through Kolbs cyclical learning cycle (Kolb 1984)(see Figure 4) - the process needs ‘feeding’ at each stage and while a certain amount of self reflection will naturally happen it is important that the facilitator encourages higher level of maturity to develop through each cycle. This ‘feeding’ may come in the form of abstraction or through changed criteria and emphasis. For example in any given design project the question of *biodegradability of materials* may be foremost in the hierarchy of the brief but if the same project were to be approached again by the learner they would benefit in a change from *biodegradability* to *compostability* as a subtle but significant design criteria. This variation in the project on a progressive basis over time encourages the learner to reflect constantly on the appropriateness of their solutions, it more importantly gives them the wisdom to apply multiple solutions to any given design challenge.

Taking the same example as cited in the ‘feeding’ section (7.2) where second year undergraduate students were given two opposing perspectives on the human contribution to global warming it was observed that students go through a balancing process in their observation and reflection. By encouraging and feeding the debate at one level it encourages the learner to challenge their own perspective and to observe and reflect on their initial standpoint. The knowledge *per se* in this case can be presented in favour of each side of the issue; the evidence does currently suggest that the human contribution is a real factor. The debate then takes on an element of quantifying how much and what effect that human contribution is ‘perceived’ to be.

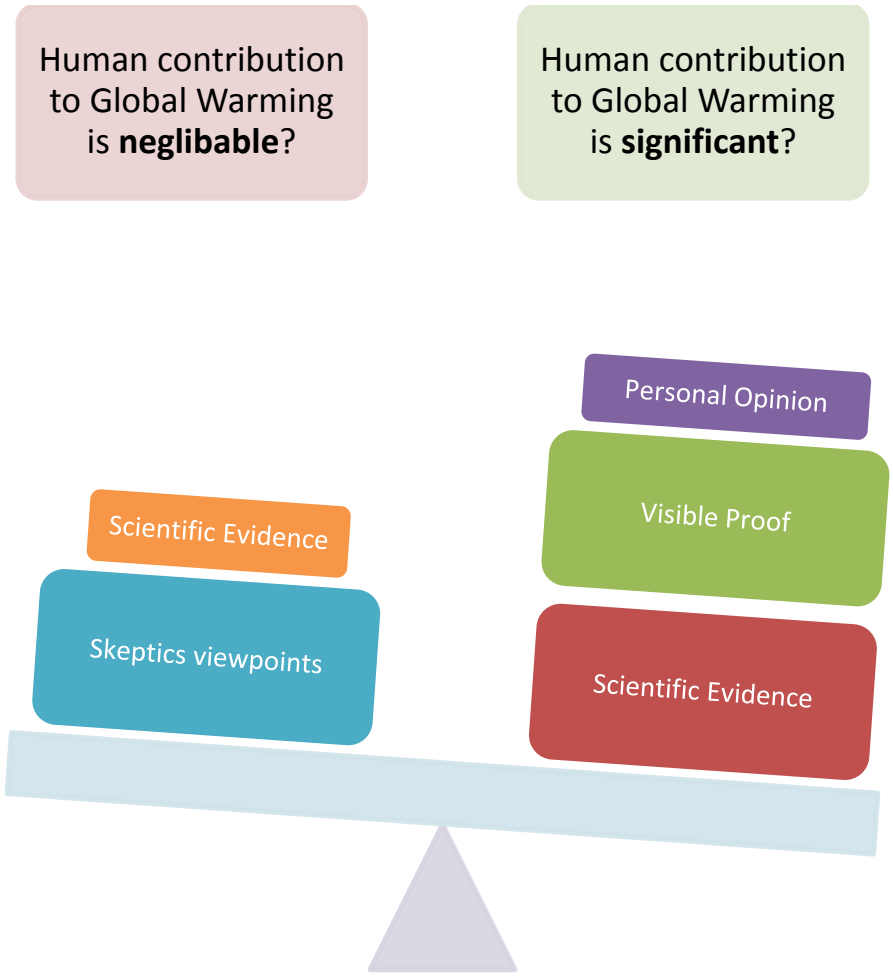


Figure 38: The balancing of perception

The learner needs to be encouraged to go through this balancing process for as much of their knowledge as possible with respects to sustainable design. It is by rationalising and contextualising the sustainability issues that the learner gains the most solid foundation for their design intent. The wisdom and maturity then develops as part of an ongoing cyclical process of inquiry and re-evaluation. The intention here must be towards building a design maturity that is meaningful.

The SDI program attempted to exemplify this process by introducing a formal peer review process at the latter stages of the course. The peer-to-peer assessment and peer to peer discussion was shown to clearly benefit students who would otherwise have remained content in their final project solutions. Peer evaluation and review if managed can be both constructive and critical and can offer the learner a benchmark by which to gauge their practice.

The intention here must be towards building a design maturity that has depth and that allows the learner to have skills and competencies that can iterate their maturity. As in the continuum proposed by Mc Mullin et al (McMullin 2005) (see Figure 39).

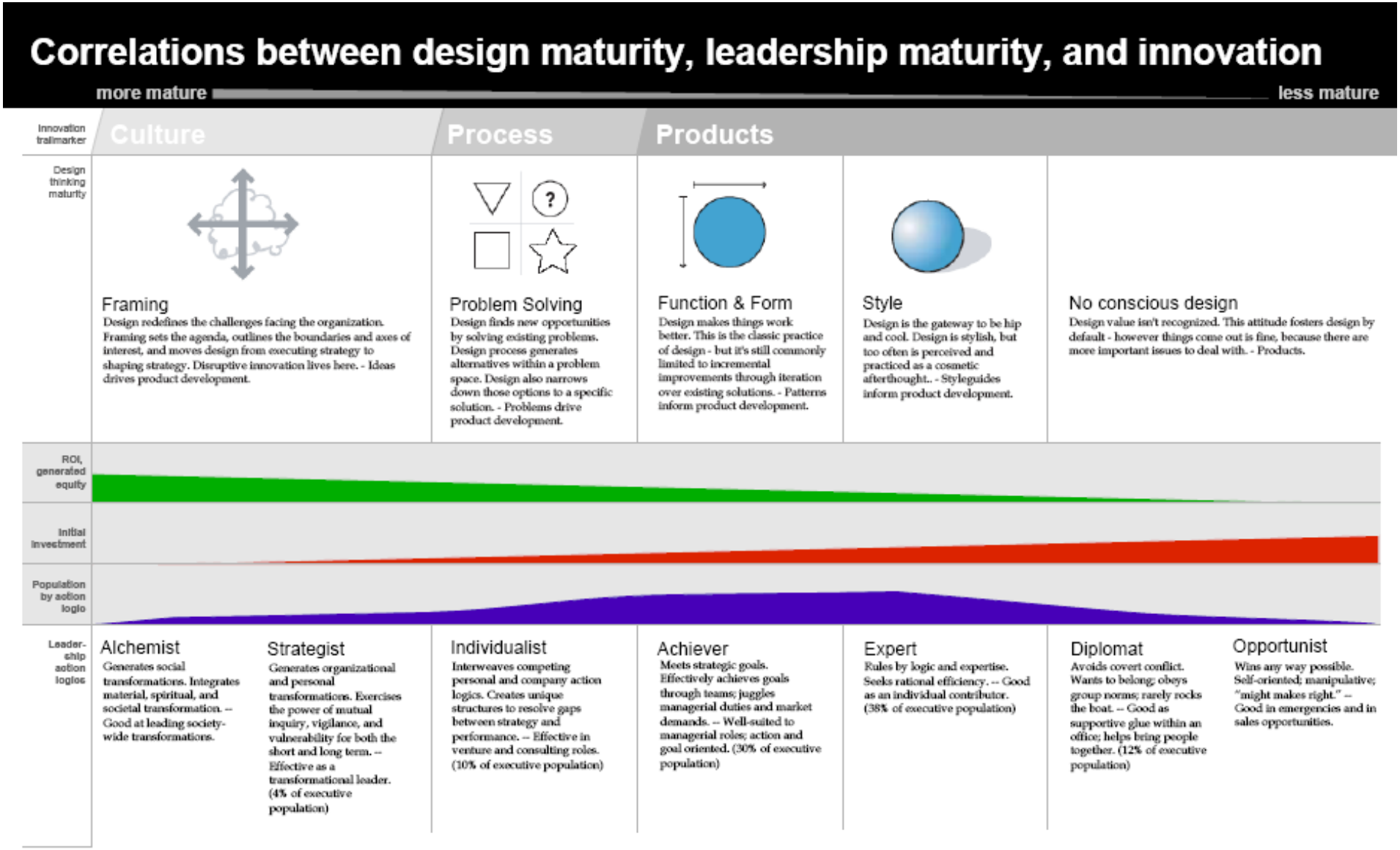


Figure 39: Design Maturity Continuum by Jess McMullin (McMullin 2005)

In this case we can see the designer or the business professional assuming a number of possible roles from ‘opportunist’ to ‘alchemist’. The learner may have a perception of where they see their skills and competencies lying in terms of their practice however this research has shown that sustainable design thinking, for it to be most effective in practice, needs to develop alchemists and strategists as well as experts and diplomats. Of course what Mc Mullin is describing here is a leadership model as well as a design model. This poses possibilities for further research that were outside the scope of this study- the question of design leadership within a sustainability field- In principle a sustainable designer/thinker if well informed, mature, wise and creative should be able to lead business, new product development and even society in some cases towards a more sustainable paradigm (see 9.5.)

7.5 Innovation and Cross Pollenization (The Bees)

This element of the model is perhaps the one that creates the most unquantifiable results. Traditional educational models do experience inter and multi disciplinary interaction (cross pollenization) but unless it is specifically placed as intent in to a course syllabus it can be haphazard.

> Innovation . . . is generally understood as the successful introduction of a new thing or method . . . Innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services.
> (Staff *et al*. 2003)

Innovation in dealing with sustainability is an essential part of the mix, what is clear from the research is that innovative ideas are possible and more probable when multidisciplinary learning is facilitated. The SDI course iterated this concept through the subtle connections that the different designers made between the approaches that their specific disciplines were espousing. For example the architects came to the course with a focus on building energy efficiency and the approach that suggested that heavily technological HRVs (Heat Recovery Ventilation) were key to improving efficiency and that services within a building generally needed to be mechanised to be effective (Sewage, Lighting, Heating etc.).

In interacting with the product, interior and permaculture designers they came to the conclusion that passive systems may be more effective in terms of energy efficiency and user habit and that they offered viable and sustainable alternatives to the some of the current ‘eco-solutions’.

The unique element in sustainable design, when approached from a teaching and learning strategy perspective, is that the cross-pollenization can happen through a number of vehicles. Sustainability offers multiple disciplines, social science, engineering, science, design and business the opportunity to collaborate towards a common goal. In fact, it is clear that disciplines working on their own will be unlikely to change the paradigm.

Within education the facilitator needs themselves to have a broad base of knowledge in order to effectively engage with multidisciplinary teams. Again on the SDI course it was found that a lone facilitator was not sufficiently effective to be able to handle the complexity of issues that were being shared. Of course this does depend on the facilitator but simple issues like the facilitator's allegiances and their own area of specialism all affect the pollenization process. The facilitators need to be able to pick up on the subtle undercurrents and connections that happen over the duration of the interaction and be able to encourage where needed and step back when not.

The multidisciplinary environment may be just the 'space' and time to explore and develop ideas in a safe environment as was found at the ReForm seminars. It was noted that in the ReForm Seminar of 2006 and 2007 there was a greater degree of new ideas forming from the facilitated workshops. The face to face interaction and discussions were key to this. In 2008 and 2009 there was a differing dynamic as the focus shifted to more detailed workshop topics. In feedback from participants it was suggested that the videoconference format that was chosen for the later two years provided a complication that rendered the workshops less effective. A balance clearly needs to be struck between quantities of multiple-discipline participation and quality of discourse between them.

7.6 New Growth and Cyclical Self Fertilization

Perhaps one of the elements of this model that has the most possibility in sustainability terms is the opportunity for new innovation and growth. As each new environmental, social and economic challenge becomes clearer there is room for individuals and companies to address these issues with innovative new methods. This creates a very different vista when compared to traditional design and business opportunity where practitioners are normally restricted to working on incremental change and re-workings of older solutions within the capitalist model. Of course technological breakthroughs do offer exciting opportunities for designers but writers such as Lawson (Lawson 2006) and Papanek (Papanek 1995) suggest that we have now - as mainstream designers- settled in to a practice of serving industry rather than leading it.

Sustainable design offers at very least a new opportunity for designers to re-visit its basic principles i.e. user centred, fit for purpose, communicative, emotive and life changing solutions to real issues and problems.
In addition over the past two years (2008/09) there are clear signs that sustainable design offers a commercial viability to both graduating and practicing designers and business disciplines. What is commonly known as the 'Green Economy'(DCENR 2009; UNEP 2008) is one of the few areas of growth in an otherwise gloomy global economic environment. The graduate students interviewed as part of this research (see **Table 3:** Interview responses from graduate ID students) showed the early signs of this opportunity and in the SDI feedback (Appendix D) the participants indicated that the opportunities for them to re-focus their practice were clear.

As with the long term maturity of the case study participants it has been difficult to assess fully the impact of the learning on them in terms of their ability to grow new business for themselves. The hope is that students will have the knowledge to apply to current sustainability challenges that they encounter but in the longer term it is intended that students will have sufficient skills and education to be able to update their knowledge and re-work their skills. The important follow-on actions are really for the students themselves to act upon. Their first projects in industry (if they are new graduates) will offer them the opportunity to implement all of the skills they have developed in their design education but also if given the opportunity they will take on the newer challenges around developing sustainable products and services. It is with these industry projects that they will start to fully understand the difficult tasks that business and designers face.

All that education can realistically do is to offer support to students and learners as they develop their careers and offer knowledge transfer and research to business that need specialist approaches. The more students that develop their sustainability skills while in university and industry, the more advocates for change there are to work with. As yet while there is opportunity and possibility for sustainable design there still has not been a clear demand from industry for this skillset within graduates. There are indications that the new growth in the green economy is happening and consequently that students with skills in this area will be at a distinct advantage in the near future.

7.7 Summary of Proposed SDL Model

7.7.1 Stages

The detailed descriptions outlined above show how a holistic model of Sustainable design learning can be achieved. The stages outlined give a structure upon which to build a sustainable design curriculum. In principle it seems that these stages are universal to each of the learner groups that were researched here – all learner groups ideally need to go through these stages in order to develop a rounded set of knowledge, skills and competencies in sustainable design.

1. Opening Awareness (The Acorn)
2. Feeding the Debate (The Germinating Seedling)
3. Forming Pragmatic Strategy Through Experience (The Sapling)
4. Observation, Reflection, Wisdom and Maturity (The Oak Tree)
5. Innovation and Cross Pollenization (The Bees)
6. New Growth and Cyclical Self Fertilization

7.7.2 Tools

The research has shown that the tools that are appropriate to use for the education of specific groups in sustainable design vary as the above stages are developed, however the tools can be summarised as follows:

Under Graduate Tools

For Undergraduate groups the tools vary considerably depending on their level of experience.

- Earlier years - Observational exercises(5.2.5), Debate (5.2.3), Case Study(5.3), Blue Sky or Divergent Thinking projects (5.4.2), Short Charettes and or challenges based on simple design problems(5.4.2 & 5.3)
- Later years- More developed case studies (4.4.2), Detailed design projects with more complex systems and SPSS requirements(4.4.3& 4.4.4), Self Directed learning and Self Driven Projects.(4.4.4)

SME Tools

For SD educational work with SME groups or individual SME representatives the appropriate tools include:

- Short informative workshops (4.7) followed closely by applied workshops which enable the participants to quickly develop short, medium and longer term opportunities for their business.

- Networking and Knowledge Transfer activities (as in 5.4 and 4.4.4). These allow for sharing of ideas, mutual benefit and cross pollenization of expertise between students and professionals.

CPD Tools

Continuing Professional Development requires a flexible set of tools that can be selected to suit the particular CPD program. The overarching intent must be one of holistic CPD and not just specialist knowledge.

- All of the above are appropriate
- Specialist workshops on specific skills, tools or areas of emergent opportunity.
- Using 'Communities of Practice' as an educational development tool as well as a networking opportunity (as in 5.5.6)

7.7.3 Strategic Considerations for Curriculum Development

There are a number of strategic considerations that need to be examined and contextualised in any development of a sustainable design curriculum. These are open to interpretation by the developers but as much as possible a pragmatic approach to 'working with what one has' is important. There are few substitutes for enthusiasm, hard work and a positive approach. The key considerations that were evidenced by the research to be important are:

- *External environment*
- *Institutional support*
- *Resources*
- *Assessment mode*
- *Style of delivery*
- *Prior knowledge*
- *Student commitment*
- *Allowance for diversity of opinion*
- *The human resource capabilities*

8 Observations and Conclusions

8.1 General Observations

It is clear from all stages of the research that the process of learning about sustainable design is complex, that the assimilation of the knowledge is a challenge to even the motivated and interested student and that the application of that knowledge through their skills is the greatest challenge of all.

What is also clear is that no singular strategy for teaching and learning of adults can be applied to sustainable development and design without limiting the holistic approach that is needed. The thesis aims to illustrate the journey that the research has taken over a five year period and it is clear that much innovation in teaching strategy has occurred.

The particular mix, whether it be undergraduate work, work by the SME representatives or the CPD learning, taken on by all the participants in this research has been illuminating in terms of attempting to show how adults, at whatever level they are at, are open to education. They show great flexibility when challenged with new issues, they show enthusiasm when tackling real problems and they show that given the right environment real and meaningful learning can continue to take place. Sustainability as outlined here is a constantly shifting area of focus with ever more critical consequences to the decisions that we take as individuals, businesses or societies. Some have approached the issues as somehow static but this research illustrates the need for students to be able to take account of the changes that occur, whether they are perceived or real.

In the paper delivered at the EESD08 conference by this researcher the analogy was made that sustainable design was akin to surfing. Sustainability is like a series of waves that are constantly building and forming as they reach the shoreline. The surfer in this case is akin to the student or practitioner - if they have developed the skills, knowledge and competencies around sustainability they are in a position to ride this and other waves - if they are poor surfers they generally flounder about in the white water!

The educational and andrologogical intents need to be very clearly thought out and planned by the course facilitators and the lecturers involved. Through this the students are normally engaged with the subject and clear about what this new learning can deliver for them. All this considered the greater challenge facing education now is one of policy and direction. It has been alluded to in the research that it is critical for the resources and policy direction to be clearly in favour of a quality of education that is meaningful and holistic. For those outside the

educational field this is often taken as an assumption rather than appreciating that these things come at a cost. Studio based learning, multidisciplinary facilitation, facilitation of small self-directed learning groups and the delivery of high quality expertise to industry and professionals all come with a higher price tag than the traditional model. They of course require more contact with students, usually they require dedicated studio space and facilities and in the case of CPD they need both on and offline flexible delivery methods. Funding mechanisms and policy emphasis within higher education needs to reflect this change in focus. The rhetoric from policy makers who espouse lifelong learning and flexible learning modes needs to be backed with the appropriate support. This research has largely focused on the teaching learning strategies around sustainable design and deliberately left to one side the resource implications of these as they could form a whole separate study.

There are some limitations that were observed in the research. These include the realities that surround the delivery of content and the co-ordination of work. Design education as has been observed, relies on a mix of specialist facilitators working together towards a final solution with the students. The specialism's come to the fore at different stages of the project. With sustainable design education there is a need for all facilitators to have a degree of understanding of how sustainability can impact on their area. Research, concept generation, manufacturing and materials selection along with human factors and visualisation all need to embody the principles of sustainable design for the designs to be holistic.

It was a real challenge to develop the sustainable literacy of the teaching staff in all of the case studies that are outlined. Staff are busy and their own CPD usually focuses on their specialist interest and area of responsibility. They are interested in sustainable design however it takes a core group with consent from other teaching staff to ensure that it is kept high on the educational agenda.

8.2 Undergraduates

The research undertaken with the variety of undergraduate groups was perhaps the most useful aspect of the overall research. It was clear from the start that the introduction of sustainable design thinking and practice to the courses at IT Carlow and to a lesser extent the partner institutions was going to be a long process with challenging obstacles to overcome.

As with any new syllabus development or course focus the inclusion of sustainable design requires an advocate and the support of a team of facilitators. The design staff at IT Carlow proved to be open to the introductions of this new direction and showed humility in being able

to learn with the students throughout the process. Assisted by the research in the form of the ReForm seminars, the live projects and their own individual interests and specialism, they clearly demonstrated the ability of design educators to adapt to the changing societal needs. Perhaps more importantly the staff provided a solid sounding board for all stages of the research and that ‘community of practice’, as described by Etienne Wenger ,is one of the critical elements for any practitioner or researcher (Wenger 1999). In order for research to be applied one needs regular critique and debate. The process for the educator is similar in the development of new syllabi and initiatives. For them to be robust they must stand up to harsh criticism and for them to be justifiable in the educational and business context they need to be shown to be effective. This is not always achievable - there are times when poorly thought out briefs or projects clearly do not engage the student and of all the proofs the students’ experiences and feedback are the most telling. If attention is not paid to the detail of the module or project then very quickly the group dynamics and the educational benefit can be limited.

The undergraduate students are invariably engaged with sustainability as a focus for their design education as it provides one of a number of tangible benefits to learning design. The students perceive this type of design to have direct benefit and to help to solve many of the daily issues and problems they see in daily life. For them, it can be a fresh and ever changing area and it provides real opportunity for creative ideas and innovative approaches to feed their design practice. The complexity that successful sustainable design requires in many cases has shown to be a benefit to students who excel at systems thinking and holistic creativity.

In addition to the above observations it has been clear throughout the research that students are encouraged by the self directed nature of much sustainable design educational work. They engage enthusiastically when challenged with group projects and communal goals that have the possibility to benefit society or the environment. The benefits are not always immediately apparent to them when doing multidisciplinary projects, but the research is clear in showing that they do benefit in the longer term and they do, on reflection, value the interaction with other disciplines.

The challenges and limitations that were observed within undergraduate sustainable design education included the standard issues of resource allocations, the need for adequate space and time to critique and evaluate the work with the students. It was also observed that the student’s perceptions of environmental and social issues need to be constantly challenged to ensure both an informed and an objective view on which to base their design work.

So summarise the key observations from the undergraduates included:

- A long and detailed process of integration of sustainable design in to course syllabus and modules is necessary.
- Staff need to be consulted and encouraged to take ownership of sustainability in their specialist area.
- Community of Practice amongst staff is important to ensure robust content.
- Students generally engage positively and enthusiastically with sustainable design in the appropriate learning environment.
- Perceptions on environmental, social and economic issues need to be challenged.
- Space, facilities and time are important elements in sustainable design education.

8.3 SMEs

The work undertaken through the Winnovate project and subsequent initiatives through both the ReForm seminars and live projects ensured that there was a broad base of interaction with SMEs on which to draw conclusions. SMEs – or more importantly their representatives- clearly need subtly different strategies for sustainable design education when compared with undergraduates and design professionals.

The SME representative does not necessarily come from a design background and so often traditional design thinking is an alien concept. They do however have a pragmatic and industry focused set of skills that allow them to be very astute as to their needs. Education can offer them the possibility to broaden their outlook when it comes to new product development and clearly many SMEs struggle with this. Sustainable NPD offers the SME the chance to develop these skills but also to grow in one of the few areas of western economy that is not contracting in recent years.

The SME learners that worked with the case studies in this research showed a capacity to adjust their approach to manufacturing, design, marketing and systems when sustainability was put at the forefront. They were able in the short workshop environments to bring their considerable knowledge of these areas to bear on creative solutions. In the main the SME learners did have an apprehension about their lack of knowledge and the ability of their company to change its practice holistically. ‘Greenwashing’ was clearly seen as the immediate step in a process of change. Many SMEs do not have the luxury or see the necessity for up skilling their workforce but those that engaged with the initiatives outline in this research showed how they were both willing and able to work with both academia and

each other. A staged approach to their education in sustainable design was clearly more beneficial, i.e. moving from introductory workshops to working with undergraduate students as a means of safely visualising sustainable possibilities for new product ranges. It would be naive to think that academia can provide all of the SME educational needs when it come to sustainable design as small Industry tends to react to market trends and demands from customers rather than to respond to strategic goals. The SMEs that engaged with the case studies were observed as being very adept at developing their sustainable literacy so as they can engage with their customers.

The limitations from the Winnovate case studies and the live projects are clearly around developing strategic sustainable thinking with SMEs. The grant assistance offered by Enterprise Ireland, Inter Trade Ireland and Sustainable Energy Ireland all push SMEs towards incremental change within very tightly defined boundaries. There are clear signs also that SMEs suffer from initiative overload from state agencies and academia and so any further engagement needs to be channelled in a more strategic manner.

The Design CORE at IT Carlow will continue to work with SMEs on developing their sustainable design capability. Further opportunities to work collaboratively between regions and develop local areas of expertise was seen as beneficial to both the SMEs and the academic partners. The development of the human capital of sustainable design expertise within SMEs largely depends on the desire of the customer base to have more sustainable products and service systems.

The key observations from the SMEs included:

- SMEs require short and highly relevant introductory workshops on specific sustainability topics - LCA, Materials Selection, Energy, Socially responsible manufacture.
- They need follow up with exemplar projects that show the possibilities for sustainable NPD.
- They learn in a less strategic manner to other groups as they tend to respond to the needs of customers rather than leading change.
- Innovation is important to their business and they appreciate the need to be at the forefront of sustainable innovation in order to survive.
- Time and ability to commit to extended courses or initiatives is their main limitation- flexibility and personal contact from the educators is all important in overcoming this.

- Successful SMEs show resilience to change and a desire to engage with sustainable design education either in a knowledge transfer capacity or a professional development mode.

8.4 CPD for Design Professionals

The process of developing and piloting the SDI module was a clear opportunity to test in full the key aspects that were developed through the four years of preceding research. It was an ideal environment in which to test the methodologies and androgogical approach to teaching and learning of sustainable design.

The observations relevant to the research in this case are ongoing as the course has only completed one cycle but at this stage it can be stated that the strategy of co-design, expert mentoring and lecturing and a close co-ordination of on and off-line activity did benefit the professional learners.

The fact that no course of this type had been in existence in Ireland previously meant that there was an effective blank slate in terms of developing a course that was specifically targeted towards professionals and also that tested the models developed with other elements of the research with a more discerning learner group.

The fact that the learners were direct peers of both the facilitators and expert visiting lecturers in this case added to the challenge. It was observed that working with the co-design group initially to frame the syllabus was hugely beneficial and then during the pilot course it was possible also to adjust the tempo and style of delivery to best accommodate the group involved. This clearly illustrated the benefit of stakeholder involvement within the educational process.

There is always a risk with a new course in the first year that the enthusiasm of both participants and facilitators ensures that the course is ideally run however the continuing challenge will be in sustaining the course over the longer term. The process of setting up a new program such as this is fraught with obstacles and challenges, institutional approval, validation, funding, promotion, personality clashes and communication issues. This course was not without its share of these issues however the course did run as planned, the validation process -through HETAC- at national level is has been completed and the support of the professional body in this case, Design Ireland Skillsnet, was most valuable. The learner group gave detailed feedback as was suggested previously (see 5.5.6) and this

feedback was overwhelmingly positive. All participants when asked agreed that the course lived up to their expectations (In five cases it exceeded their expectations).

The professional learners were observed to be more engaged than the undergraduate learners, their time is valuable to them and they are much more discerning about how they use it. There was a clear desire on all parts to engage with the module fully (often with undergraduate modules there can be an element of reluctance from some students). The qualification (in this case a level 9 certificates and exemption on the MBA program) was less of a motivation than was expected and the participants clearly valued the course content and delivery for its own sake.

It was also clear that they valued the opportunity to engage with their peers in an educational environment. It was observed that they saw sustainable design as a new and mutually beneficial field within which they could collaborate with other design disciplines and that the creative linking opportunities were valuable.

In choosing the personal projects the participants seemed to value the opportunity to explore an element of their own practice from a sustainability perspective. The participants did comment that the course opened up many possibilities for them and started their questioning of their own practice. Materials selection, LCA, Eco Labelling and energy rating all featured highly on their priorities list at the beginning of the course but importantly they left the course with the knowledge, confidence and critical questioning to better use these skills. They are now able to identify the areas for their business that they need to develop further from a sustainable design perspective.

Some of the endorsements from the SDI course as verbalised in the formal feedback (Appendix D) perhaps are the most telling in terms of participant feedback- Below are a selection of participant quotes from 2009 :

> SDI helped to give me the capacity to address and implement sustainable design within our practice Norman Stevenson (Senior Industrial Designer with Design Partners)

> This course is not about the plethora of 'Post -It' type solutions available today, It is about fundamental philosophy and knowledge to see through the volumes of misinformation and dubious solutions used to 'Greenwash' products , processes and companies, Outstanding- David Mavroudis (Architect)

> There are so many buzz words around sustainability these days. A course like this goes back to first principles and gives foundation to an understanding of what they actually mean and represent. Putting the theory into practice is the place that a course like this can be a catalyst for any person across diferent disciplines- Patrick Shaffery (Architect)
>
> It opened my eyes to many obstacles that have to be overcome but showed me the strategies and pathways to overcome them Bernadette Douglas- (Industrial Designer)
>
> Sustainability is happening + Designers must come to terms with this and restructure their design ethic and process. Great starter on Sustainable Design - John O'Shea (Product Design Engineer with ABS)
>
> I learned far more in the 6 months of this course about sustainability than I ever envisaged. I feel that this course has helped me become a more responsible designer and has been a great benefit to me personally. I Highly recommend it.- Gemma Shore (Graphic/Packaging Designer with Jivo)
>
> The SDI course gave me the time, structure and learning environment to reach a far greater strategic and tactical understanding of the issues, challenges and opportunities to respond to global climate and sustainability- Paul O'Connor (Architect)

(see Appendix D for full feedback)

So summarise the main observations from the design professionals included:

- Co-design of the learning outcomes enhanced by specialist experts and facilitators clearly works for sustainable design education in the professional sphere.
- Engagement and work ethic, as one would expect, is at a higher level to the undergraduate work.
- Attention to detail, tailoring of module and sequencing of the delivery are all important to the quality of the learning.
- Peer to peer learning and exchange of ideas is valuable and produces innovative results when applied to complex sustainability issues.
- A short course such as the SDI can sufficiently open the awareness and give enough knowledge to professionals for them to be able to further develop areas of importance to their business.

8.5 Limitations of Research

The research here has identified the continual need for both students and educators to challenge their own and each other's perceptions on what is sustainable. Unlike other areas of study such as science and engineering, humanities or business, where many of the base line principles are well established and taken as being the foundation for new theory and practice - sustainable development and design is constantly shifting. The base lines are complex and open to wide interpretation, they are in many senses still being formed. This proves to be a real challenge for the learner and educator alike. Sustainability is often seen as a dogma or a moral and ethical issue; this can limit it to the realm of belief and perception. The challenge for education is not only to teach pragmatic ways of implementing sustainable design but also to develop individuals so as they can respond with humility and professionalism to the critics. This research has shown that it is possible to educate even the most hardened critics to see the benefits of designing with sustainability in mind.
There is a continuing risk that education will be forced to move away from the studio based learning approach advocated here and that resources and expertise will be diluted to serve larger numbers of students. This research has clearly shown the need for education to be learner centred and not only numbers focused. For sustainable design to be taught effectively educators and institutions must continue to overcome these limitations and strive to innovate new alternatives.

There are limitations to engaging with SMEs who are only interested in short term solutions, It has proven difficult to attract the SMEs to be involved with the research and without the Winnovate programme as a vehicle for the research it may continue to be difficult to create genuine engagement. The SME involvement certainly benefits the undergraduate students however the process needs to be managed throughout and the companies and projects need to be chosen carefully.

There are more general limitations around the research that include the scalability issue. It is apparent that this research has proven successful in the localised context. The learning strategies outlined would clearly need to be customised in the context of larger learner groups or institutions that have different resourcing structures. The findings from the case studies are samples of what is possible and further quantitative work would need to be completed to show how graduates and professional apply their learning to industry.

8.6 Similarities with past work

The work outline in the body of this research has of course many similarities with the past work of others in the sustainable design education arena. A selection of these similarities is outlined below:

The work at TU Delft (de Werk 2008; de Werk and Mulder 2004) with Bootweek (5.3) has strong similarities with the SDI Module approach where a mixture of disciplines all from closely associated specialism's add considerably to the richness of discussion and problem solving ability of the group. Bootweek was a specific case study within this research and the researcher's collaboration with de Werk and Mulder have no doubt influenced the direction of some of the models. TU Delfts approach to weaving sustainable development in to almost all curricula within the university took a concerted effort and great degree of strategic thinking. The weaving of Undergraduate, SME and CPD education in sustainability here at IT Carlow has required similar strategic thinking-albeit at a less detailed and less institutional level.
There are similarities again with work in Monterey Tec, (Gaytán 2008) and in the work of Alan Findeli (Findeli 2001) .These examples look at the specific learning skills and competencies that are appropriate in sustainable design and development. Gaytán looks specifically at the issue of creativity when applied to sustainability where she concluded that sustainable design was not a barrier to creativity but in fact provided further gateways. For this research the issue of creativity was a periphery issue but one of concern to all of the developed case studies. Without the creative element design and sustainable design are reduced to formulaic responses to challenges there is no doubt that this is one of the skills that designers can really contribute to the SD field.

The work done by the groups at Loughborough University(Bhamra 2007; Lofthouse 2006) and Bournemouth University(Hutchings *et al.* 2002) show how it is possible to integrate sustainable design in to course specific syllabi in a meaningful way. Both universities have developed a reputation for sustainable design expertise at a post graduate level and while they are not alone in the UK in this regard they do provide an example of how the experiences from an educational perspective can be shared with others. This research has attempted through the Reform Seminars (5.4) and the Inter Institutional Collaborations (5.2.3& 4.5) to share experience and to collaborate with others in an attempt to show that there is benefit in pooling of expertise between institutions.
The evidence from this body of research aligns very closely with the principles espoused by a number of the key bodies of work in the field of sustainable design .The DEEDS project (DEEDS 2007) for example outlined a number of key principles that were essential to teaching sustainability. These included:

- The development of teams, communities and networks in and through design practice.
- Synergistic clusters of competence as well as inter-disciplinary thinking and practice.
- Mutual learning, creativity, team-work and Teaching and Learning (T & L) through participation.
- The development of listening, communicating, narrative and presentation skills.
- Stakeholder participation, collaboration, sharing and partnering.
- Confident engagement with business language and logic.

They went on to emphasise the three following areas of importance:

- Participation
- Mutual Learning
- A deep implied sense of inter-disciplinarianism

These areas of importance and the key teaching principles are very closely aligned to the SD learning Model as evidenced by the research.
The developed case studies proved that the holistic approach with progressive development of a student's knowledge skills and competencies is essential. The DEEDS project emphasised inter-disciplinary thinking as an ideal however the case studies and SD learning Model developed in this research focused more on multidisciplinary thinking and collaboration. This subtle difference (As described in 2.5) was driven by the evidence from the early case studies i.e. Students and professionals from multiple disciplines will collaborate on mutually beneficial SD work however true interdisciplinary fusion can only happen over a longer period when the disciplines develop a common literacy and start to work outside their discipline (as the SDI Module in 5.5.6).

These similarities with other work provide examples of where the research has overlapped or been influenced by other teams and researchers. It is by no means exhaustive as there are parallels with many of the writers and researchers outlined in the Literature Review (2.3) also. It does re-enforce the research to see that many other bodies of work have found similarities in the approach needed to develop sustainable design.

9 Conclusions

The key conclusions from this body of research indicate that it is possible, given the right learning environment, to educate students and professionals holistically in sustainable design. It is clear also that students benefit most when they are challenged and allowed to develop a sustainable design philosophy of their own that they bring in to their work (as shown in the follow on study of graduates in 5.6.1)

9.1 Addressing the Aims of the Research

The original aims of the research were as follows

1. *To evaluate current practice and approaches in other Universities and HE institutions.*
2. *To evaluate the needs of SME learners and Professionals with respect to SD*
3. *To develop a practice focused approach based on other models*
4. *To contextualise the learning approaches with respect to a rapidly changing paradigm*
5. *To compare and contrast the learning strategies of undergrads, SMEs and Professionals and to show how they progress in their learning throughout their careers.*

These were addressed successfully through the following corresponding routes:

1. The Literature Review (2.6, 2.7 and 2.9), the case study visits (5.3and 5.4) and the inter institutional workshops(5.2.3 and 4.5)
2. The prior knowledge studies of sample groups of SMEs and Professionals(4.2) and the Co-Design Workshop in the development stages of the SDI program(5.5)
3. The Exploratory Case Study (3.4), the Developed Case Study (5) and Action research (3.2) methodologies
4. The research findings from each case studies(4) and their informing of the development of the CPD program (5.5)and the Syllabus changes(6)
5. The comparisons and findings in each of the case study examples and the overall body of research (8) combined with the follow on study of graduates (5.6) and professionals from the SDI course (Appendix D)

9.2 Addressing the Objectives of the Research

The Objectives of the research were as follows:

1. *To develop a strategy for holistic learning in Sustainable Design.*
2. *To customise this strategy in to concrete learning methods for Undergraduates, SME's and Professionals*

3. *To develop, manage and facilitate a series of exemplar case studies to illustrate the strategy.*

The meeting of the objectives formed the main basis for the contribution to knowledge and it is hoped that other researchers, academics and educators find the work useful and pertinent to their own work. The meeting of the objectives can be summarised as follows:

1. The strategy was developed as both a sustainable design learning model (7) and as an approach and philosophy to implementing this model (6.1)
2. The strategy was modified and tweaked to each case study opportunity (4 & 5), The methods were customised to take account of the needs and educational requirements of each of the learner groups.(4.5.5,4.7.3,5.3.3,5.4.3,5.5.5 & 6.1.2)
3. As outlined in chapters 4& 5 the case studies were successful in showing firstly the development of the strategy and learning model for SD education but also in Chapter 5 the exemplar case studies show how the model was fine tuned for maximum educational impact.

9.3 Summarised Conclusions

This research has shown that there are subtle stages to learning about sustainable design and that as much as possible students must be facilitated and guided through these stages. The stages outlined in Figure 35 (sustainable design learning model) show how it is important to cultivate a robust and holistic understanding of the issues around sustainable design and to then grow that understanding in to a pragmatic approach through applied design activity. It is clear also that multidisciplinary activity when appropriately structured can yield huge benefits to the learner and can develop innovative and practical approaches to real issues. It is also apparent that given these conditions, in time, incremental and/or radically new ways of approaching sustainable design may occur.

SMEs, design professionals and undergraduates all clearly learn in slightly different manners and all require the learning strategy to be tailored to them and their situation. What has been re-enforced are the observations that adults learn best in a self directed, peer to peer and active learning mode. They respond to challenges by using their experience, their motivations to develop their knowledge are based on the understanding that this will empower them to better address sustainability in their work.

The research has also shown that the design process can be re-invigorated by adding sustainability considerations at an early stage and by following through with ensuring that

these issues are addressed at all stages in the process. It has become apparent through the research that learners realise that no design is fully complete in the current marketplace without considering at some levels its social, environmental and economic impacts and benefits. There are strong signs also that industry clients and customers are actively seeking sustainability benefits in any new product development and they are looking to the designers to address these issues as a matter of urgency.

It is also clear from the research that attempting to ‘green up’ elements of materials selection, manufacturing and energy efficiency education do not substitute a more holistic and integrated approach to design education. Modules and courses that attempt to offer sustainability as a lone add on have limited benefit and the research has proven that an applied element is necessary to build on any theoretical basis.

There has been a clear improvement in the sustainable literacy of the students who have been part of the case studies outlined in the research. There has been a marked acceptance over the period in the inclusion of sustainability principles as a normal part of the design process and it is fair to observe that this change in the focus of learning corresponds directly to the change in literacy that undergraduate students showed.

It is apparent that students need to develop a broad sustainable literacy throughout their education and yet often this can get lost in the overall syllabus without sustainability focused modules or projects.

There is a need to constantly review learning and teaching methods and curriculum content for sustainable design as the ‘market’ for graduates and sustainable business practitioners is constantly shifting. This research provides a basis and a set of strategies on which to build this review.

Sustainable design is one of the key ‘Trojan Horses’ which allows design graduates and design thinkers to find space to change, for the better, the services and products which society depends on socially, environmentally and economically.

9.4 A Contribution to Knowledge

This research has allowed the researcher to learn, develop and grow as a lecturer an student and to facilitate others in sustainable design. The students and professionals who participated in the five years of work have clearly gained a new level of sustainable design literacy. They have been shown to change their outlook on design and corresponding

disciplines through the work as both students and as professionals . A number of colleagues and contributors to the work have also developed their personal knowledge, experience and practice in the course of the research. These are all developments that were anticipated but ones that make the research live and applied.

The specific contribution to knowledge that this body of research offers is in the novel approach to developing educational strategies for the three stakeholder groups- Undergraduates, SME representatives and Professionals. As far as was possible to establish there has never been a comprehensive comparative study of the learning strategies of these groupings. The transition of the undergraduate in to professional life is much analysed but not specifically with respect to sustainable design. The difference in learning modes needed between SMEs and Professionals is clear also. The subtleties outlined between the professional learner and the undergraduate learners with respect to sustainable design are clear. Undergrads can take a considered and developmental approach over the duration of their studies culminating in a deep sustainable literacy and a holistic knowledge of issues, tools and strategies for dealing with these changing issues. Professionals need a more distilled approach while building on their professional experience and knowledge.

When applied and facilitated correctly, the outcomes of both approaches clearly result in designers who have a broad view of sustainable development, a specialist approach and skill set to sustainable design and an ability to communicate effectively with other related disciplines.

This body of work shows how it is possible to effectively educate students, SMEs and professionals in sustainable design so as to be able to apply their knowledge, skills and competencies to design and industry practice in an effective manner within a complex and rapidly changing world paradigm.

9.5 Further Research

The scope for further research continuing on from this body of work is exciting. There would seem to be opportunity in a number of areas that have the potential to further enhance sustainable design education and professional development.

Within the undergraduate programs offered at IT Carlow there are a number of opportunities including a possible stand alone set of modules focusing more deeply on sustainable design to compliment the fully integrated elements developed here. There is also a clear opportunity to develop a separate specialism in the area of design futures or sustainable product design at undergraduate level which may run parallel to the existing courses.

The SDI program as it currently stands has shown that there is a further need for CPD in strategic design thinking. This could be developed as a series of complimentary modules/courses that would focus on areas such as sustainable leadership, sustainable strategic planning, specific materials selection/LCA, socially responsible procurement and manufacture and technology management. These areas have been identified as possible components to a full modular Masters Program with collaboration from other institutes and universities across Europe.

Perhaps the most tangible area for continuing research is in the area of applied research projects working with postgraduate, SMEs and professionals towards specific exemplar projects that show how sustainable design can be realised. The newly developed Design CORE has given IT Carlow the vehicle to progress this research strand and it has received both external financial and institute backing to this end.

One of the most valuable elements of this research has been in the collaboration and contact with other individuals and institutions that are working on sustainable design. Many of these contacts have shown a firm interest in progressing mutually beneficial initiatives and there are research opportunities for national and international collaboration that would build on the expertise of this network of experts.

9.6 End Note

It has been a privilege to be able to work with such a diverse group of students and professionals, experts and novices, and to develop with them strategies that have proven results. The strategies developed here for sustainable design education will no doubt evolve over time as the knowledge and skills required to deal with the challenges change.

> There is no such thing as a neutral education process. Education either functions as an instrument which is used to facilitate the integration of generations into the logic of the present system and bring about conformity to it, or it becomes the 'practice of freedom', the means by which men and women deal critically with reality and discover how to participate in the transformation of their world.
>
> *Jane Thompson, drawing on Paulo Freire (Thompson 1993)*

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Appendix A. Prior Knowledge (PK) Survey Questionnaires and Data

Sustainable Product Design ***Student*** *Questionnaire*

The following Questionnaire is designed to assess your current level of understanding of issues around sustainability and environmental awareness. The questionnaire is part of ongoing research being conducted in to sustainable product design education. Your answers will only be used within the bounds of the research and will be held in confidence.

Please respond to the following items as honestly as possible:

About yourself:

Gender Female ☐ Male ☐

Course of study you are enrolled in_____

Year of Study **1** ☐ **2** ☐ **3** ☐ **4** ☐

Please indicate your level of awareness in the following areas:

<u>Environmental Legislation, Policy and Standards</u>

	Not Aware of	Aware of but could not explain	Have some Knowledge	Have Expertise In
ISO 14001	☐	☐	☐	☐
Kyoto Protocol	☐	☐	☐	☐

WEEE (Waste electrical equipment and electronics directive)	☐	☐	☐	☐
Carbon Taxing	☐	☐	☐	☐
RhoS (Restriction of Hazardous Substances directive)	☐	☐	☐	☐
Product take back schemes	☐	☐	☐	☐

Environmental Tools, Technologies and Approaches

	Not Aware of	Aware of but could not explain	Have some knowledge	Have Expertise In
Clean Technology	☐	☐	☐	☐
Clean up-Technology	☐	☐	☐	☐
Eco-Labelling	☐	☐	☐	☐
LCA (Life Cycle Assessment)	☐	☐	☐	☐
Product Life Cycle	☐	☐	☐	☐
Waste Minimisation	☐	☐	☐	☐
Renewable Energy Technologies	☐	☐	☐	☐
Tradable Permits	☐	☐	☐	☐
Recycling	☐	☐	☐	☐
Reusability	☐	☐	☐	☐
Up Cycling	☐	☐	☐	☐
Cradle to Grave Design	☐	☐	☐	☐

Cradle to Cradle Design	☐	☐	☐	☐
EIS (Environmental Impact Assessment)	☐	☐	☐	☐
Design for Disassembly	☐	☐	☐	☐
Producer Responsibility	☐	☐	☐	☐

General Environmental Issues

	Not Aware of	Aware of but could not explain	Have some knowledge	Have Expertise In
Acid Rain	☐	☐	☐	☐
Air Pollution	☐	☐	☐	☐
Solid Waste	☐	☐	☐	☐
Carbon Taxing	☐	☐	☐	☐
Water Pollution	☐	☐	☐	☐
Deforestation	☐	☐	☐	☐
Depletion of Natural Resources	☐	☐	☐	☐
Desertification	☐	☐	☐	☐
Ecosystems	☐	☐	☐	☐
Global Warming	☐	☐	☐	☐
Ozone Depletion	☐	☐	☐	☐
Salinity	☐	☐	☐	☐

How would you rate the importance of Sustainable Design/Manufacture for the following?:

	Not Important	Possibly Important	Important	Very Important
You Personally	☐	☐	☐	☐
You as a Designer	☐	☐	☐	☐
The Commercial viability of the company you might work for in the future	☐	☐	☐	☐
The Country/World Generally	☐	☐	☐	☐
Future Generations	☐	☐	☐	☐

Did you have any environmental education in Secondary or Primary school?

Yes ☐ **No** ☐

Have you had any environmental education in your current course so far?

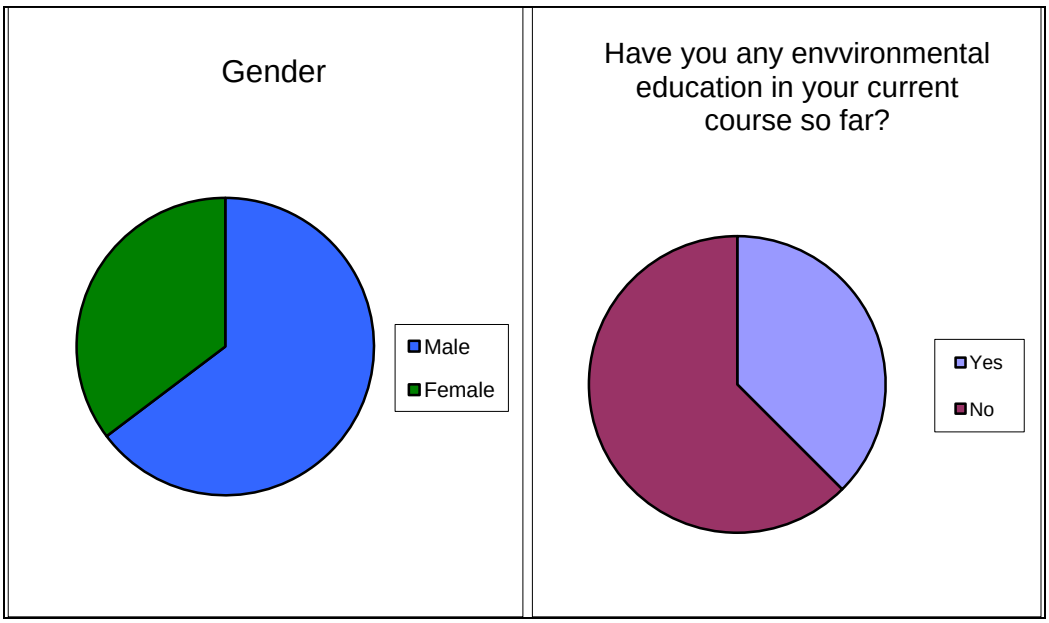
Yes ☐ **No** ☐

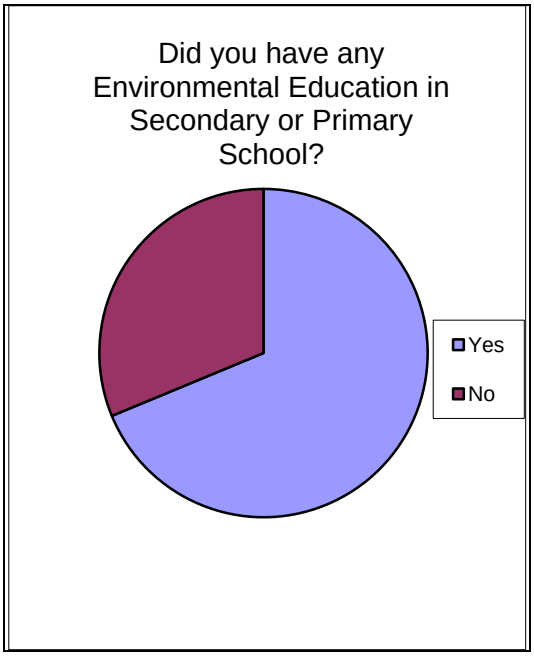
Thank you for taking the time to fill out the questionnaire.

Note: This questionnaire is based loosely on a similar global survey questionnaire design by Surrey University looking at Sustainable Development.

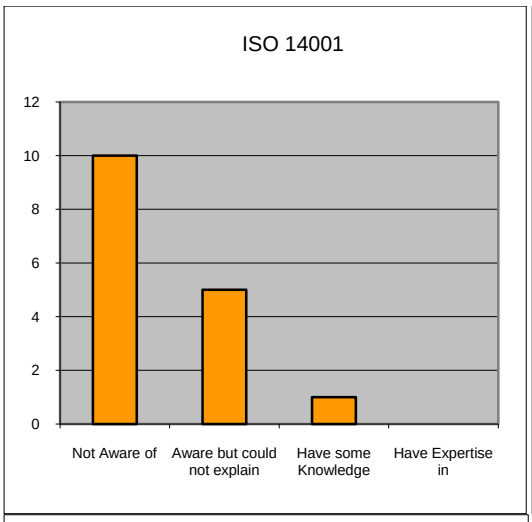
Prior Knowledge Study of 1st year Industrial Design Students @IT Carlow (2005/06) Raw Data				**16 students**
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
ISO 14001	10	5	1	0
Kyoto Protocol	9	3	4	0
WEEE	15	0	1	0
Carbon Taxing	10	5	1	0
RhoS	14	1	1	0
Product Take Back Schemes	10	4	2	0
	Male	Female		
Gender	11	6		
			Yes	No
Did you have any Environmental Education in Secondary or Primary School?			11	5
Have you any environmental education in your current course so far?			6	10
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Clean Technology	9	3	4	0
Clean up Technology	12	2	2	0
Eco Labelling	6	7	3	0
LCA (Lifecycle Assessment)	8	5	3	0
Product Lifecycle	2	6	7	1
Waste Minimisation	3	6	6	1
Renewable Energy Technologies	2	6	7	1
Tradable Permits	15	1	0	0
Recycling	0	0	8	8
Reusability	0	2	12	2
Up Cycling	9	7	0	0
Cradle to Grave Design	7	2	4	3
Cradle to Cradle Design	8	1	4	4
EIS (Environmental Impact assessment)	13	1	1	1
Design for Disassembly	9	4	2	1
Producer Responsibility	6	9	1	0
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Acid Rain	1	13	2	0
Air Pollution	1	12	3	0
Solid Waste	6	8	2	0
Carbon Taxing	7	0	8	1
Water Pollution	0	1	12	5
Deforestation	0	1	10	5
Depletion of Natural Resources	1	1	13	1
Desertification	5	5	3	3
Ecosystems	2	7	5	2
Global Warming	2	10	4	0
Ozone Depletion	1	3	9	3
Salinity	13	2	1	0
	Not Important	Possibly Important	Important	Very Important
You Personally	0	9	7	0
You As A Designer	0	2	8	6
The commercial viability of the company you might work for in the future	0	4	5	7
The Country/World Generally	1	2	3	10
Future Generations	0	1	5	10

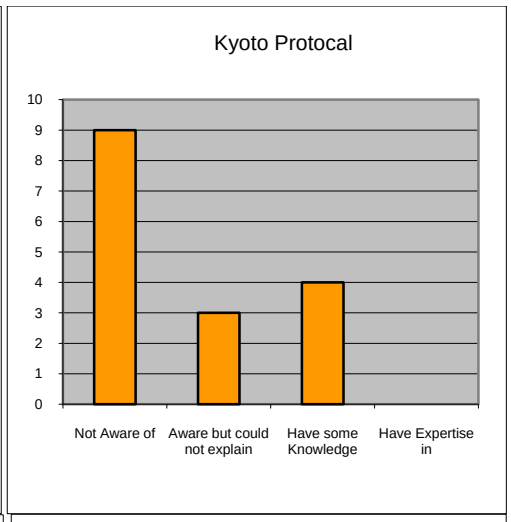
Visualised Data

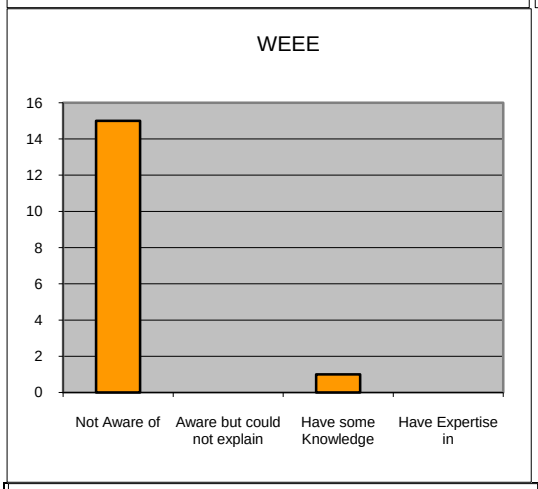


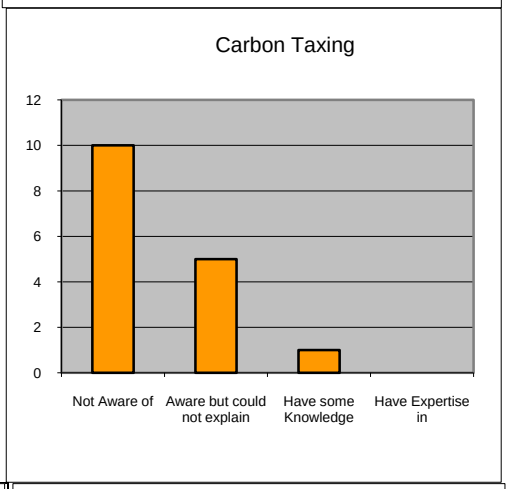


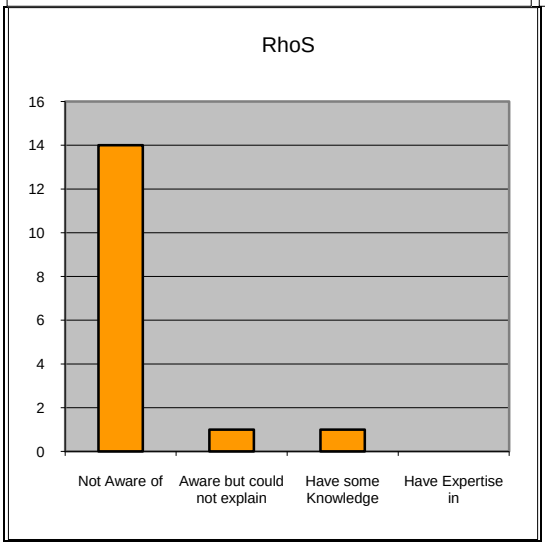
Environmental Legislation, Policy and Standards

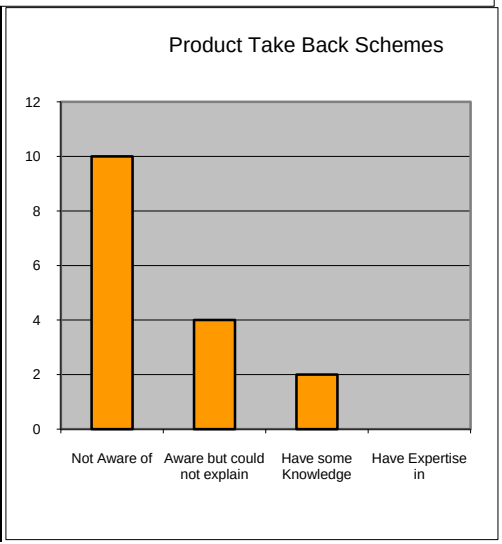




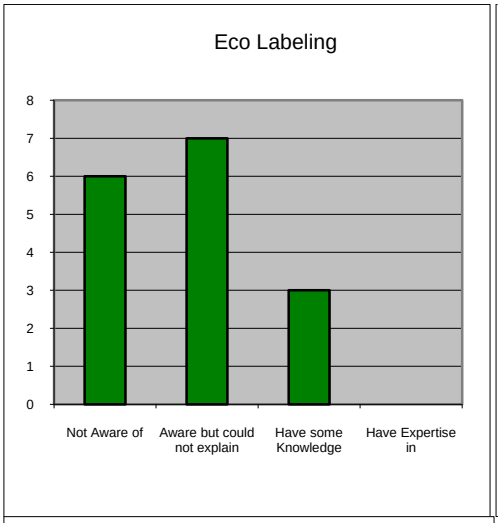


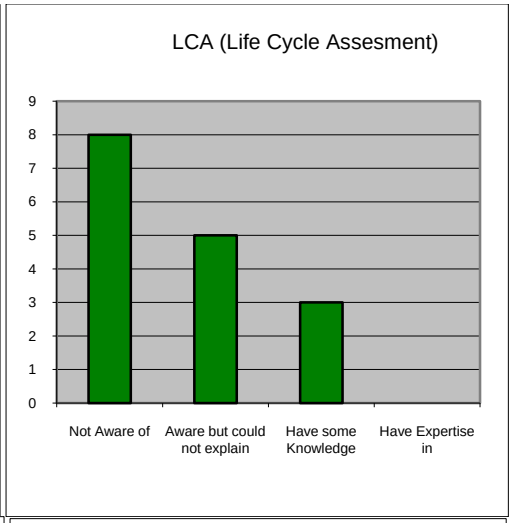


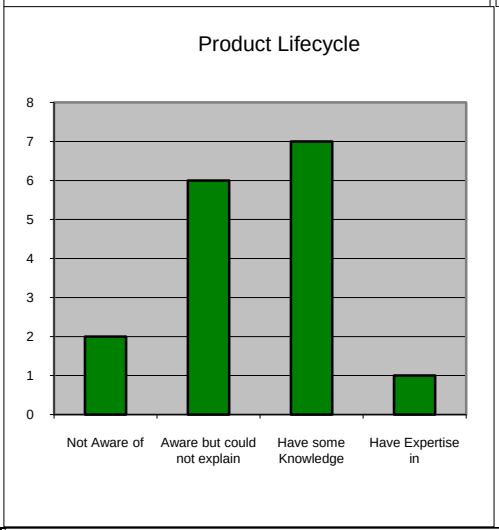


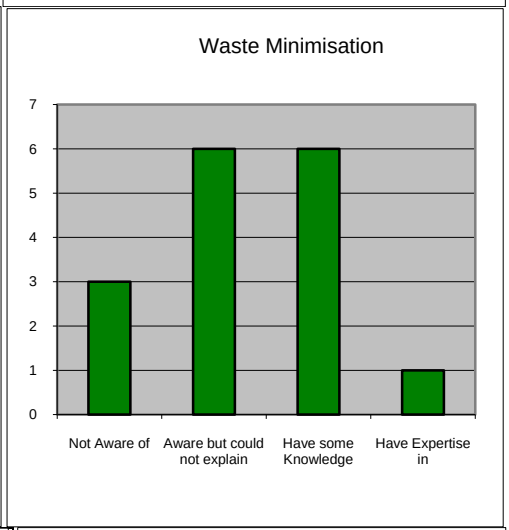


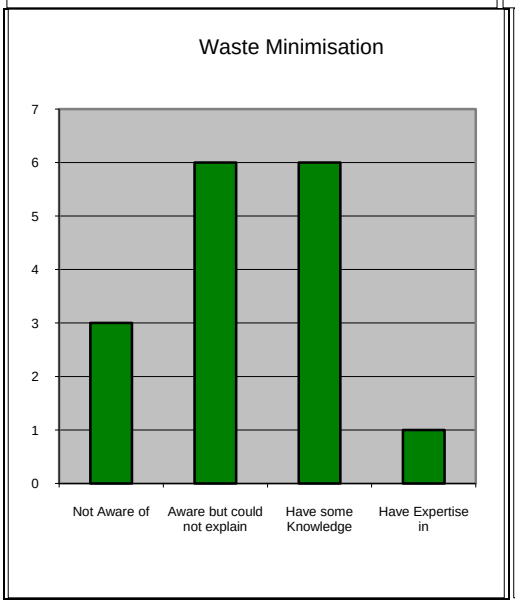
Environmental tools, Technologies and Approaches

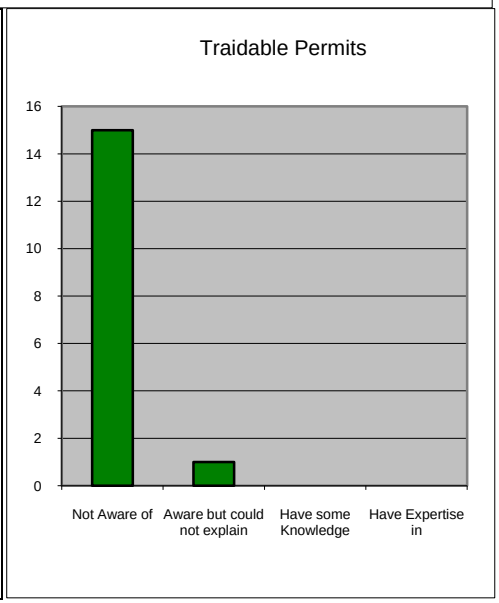




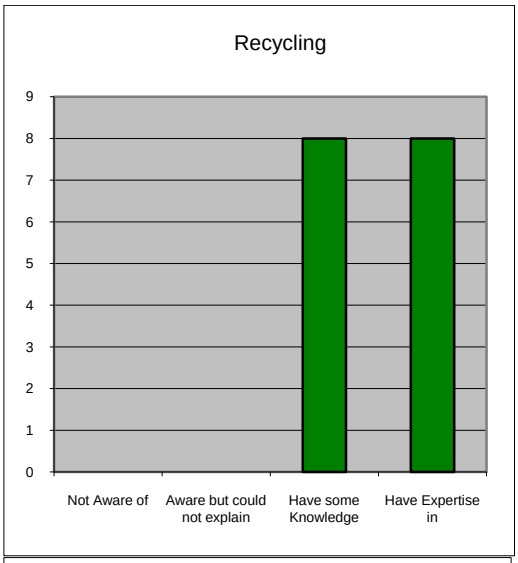


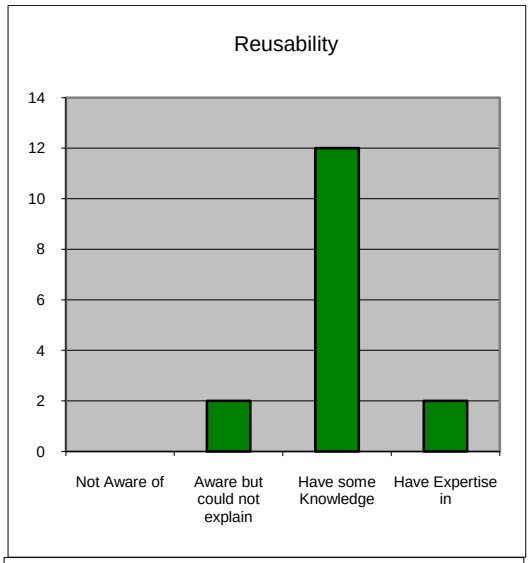


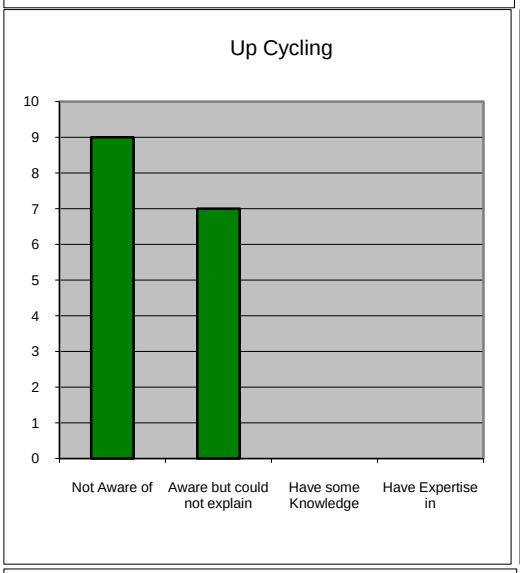


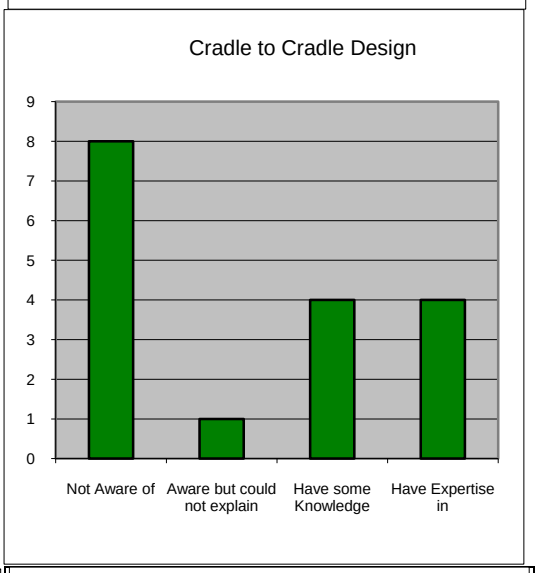


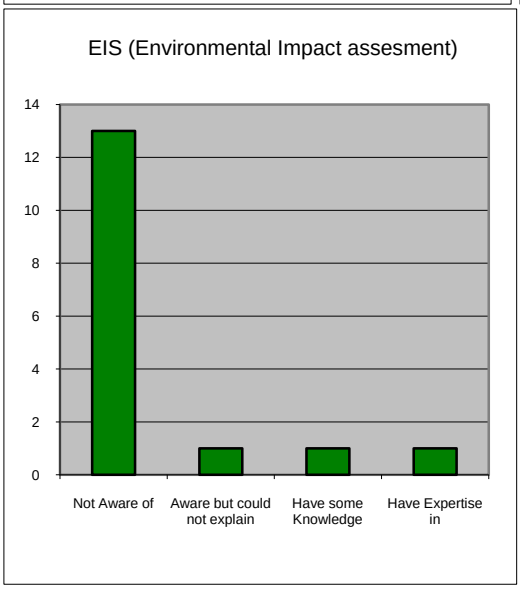
Environmental tools, Technologies and Approaches Contd.

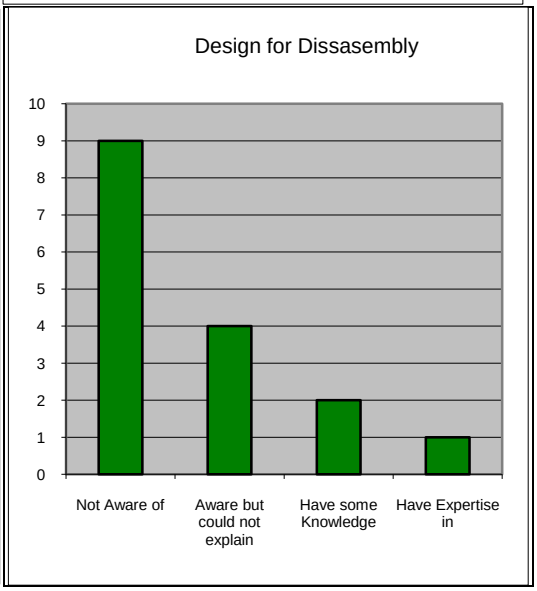












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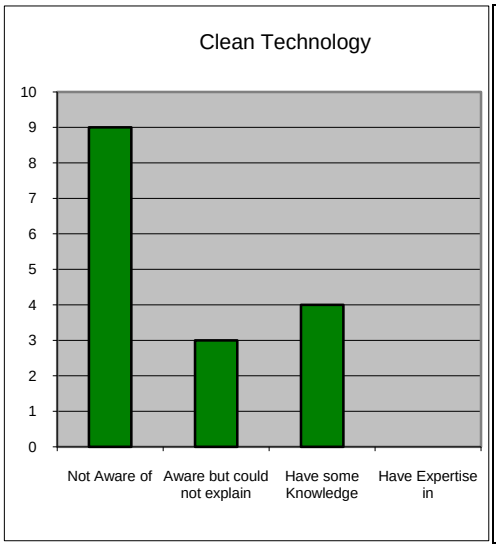
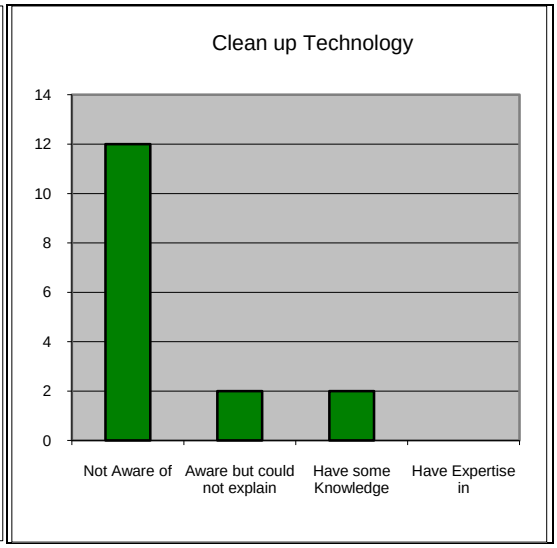
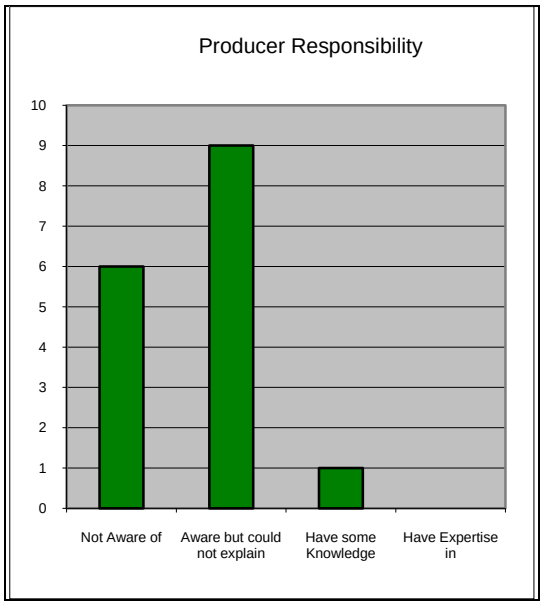
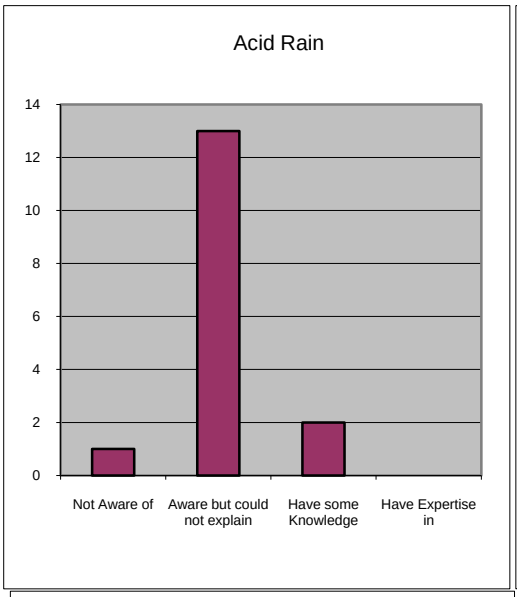
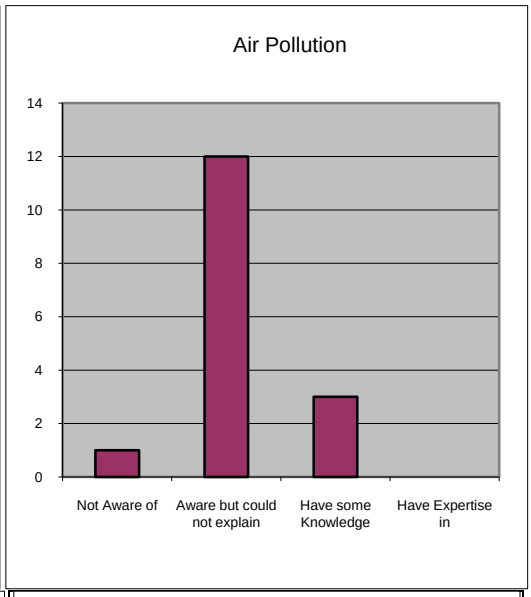


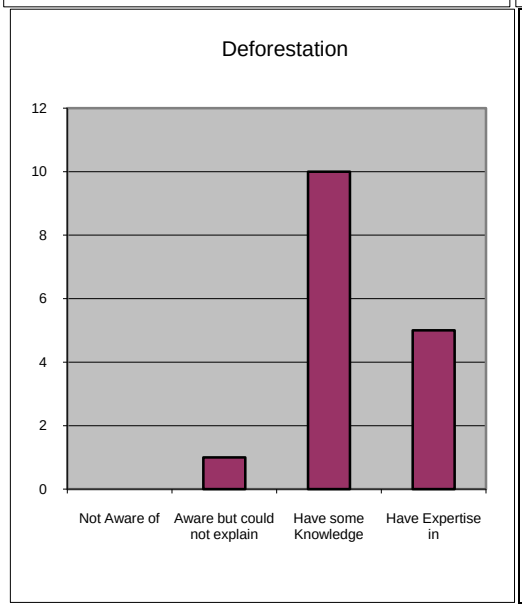


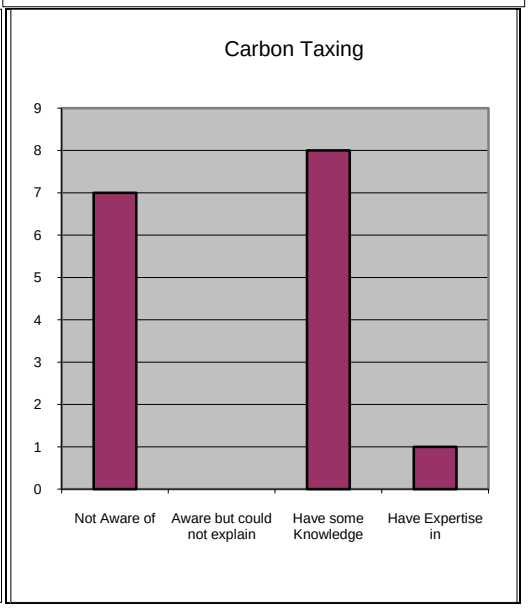


General Environmental Issues

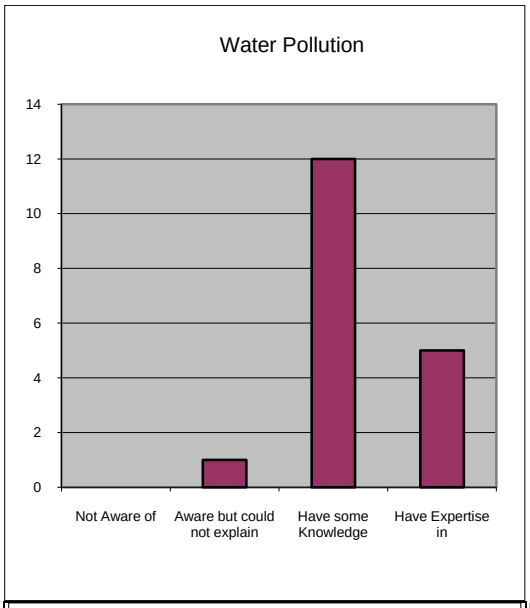


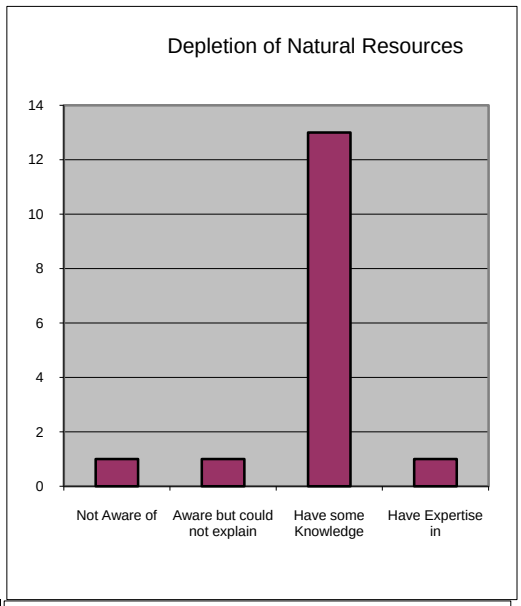


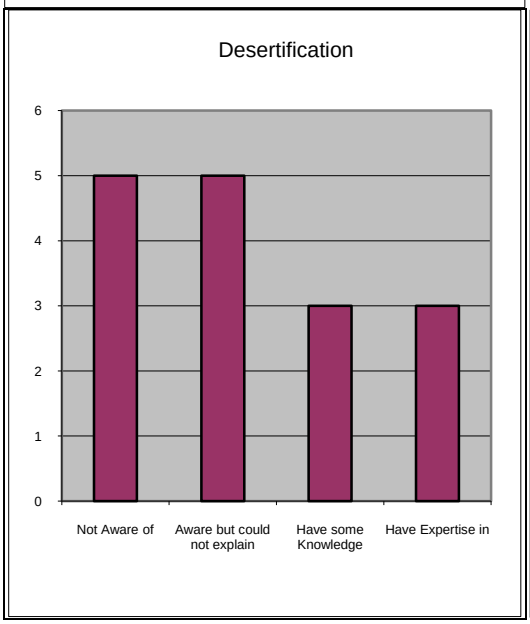


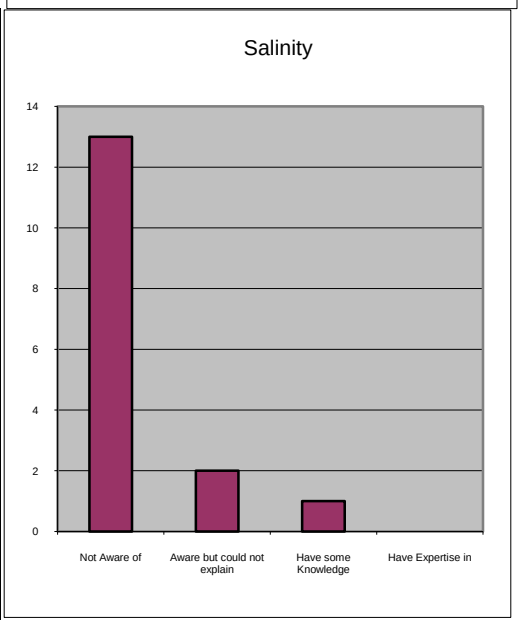


General Environmental Issues Contd.

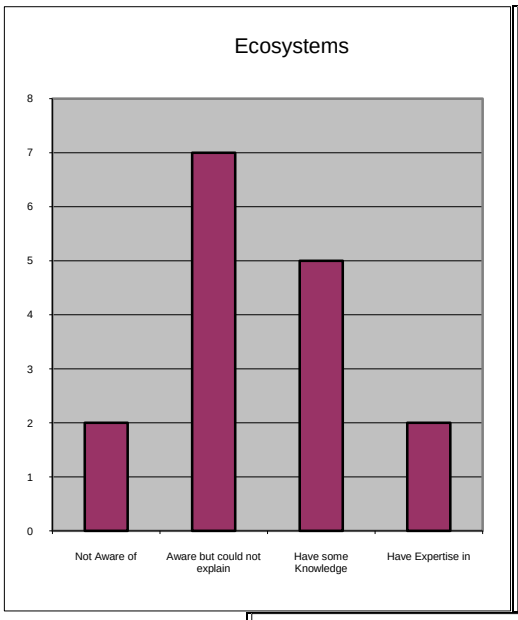


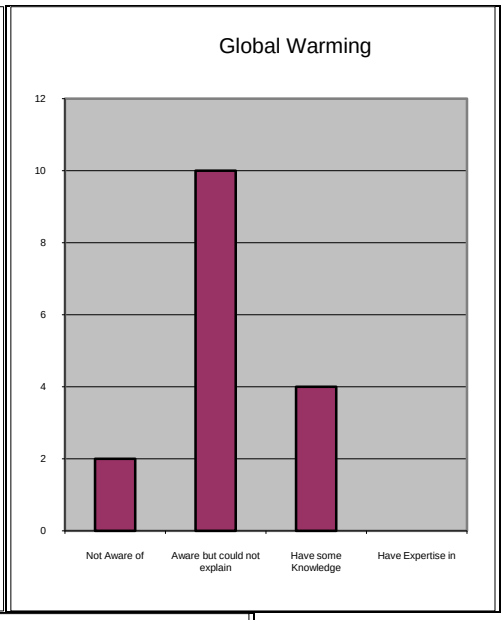


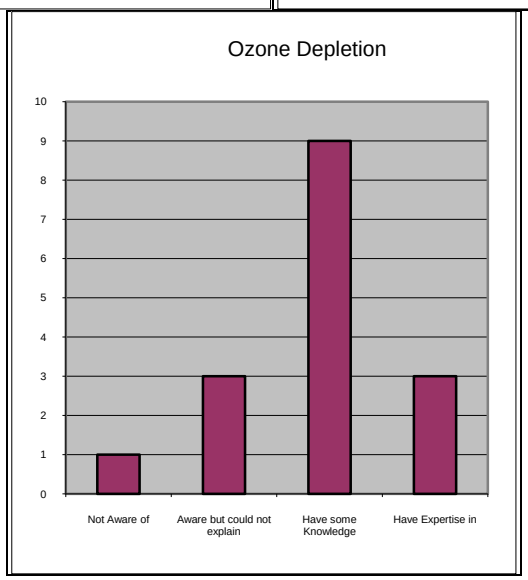




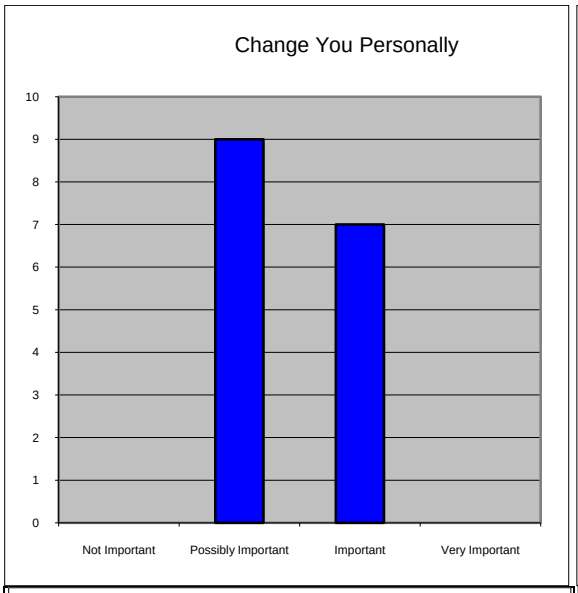
General Environmental Issues Contd.

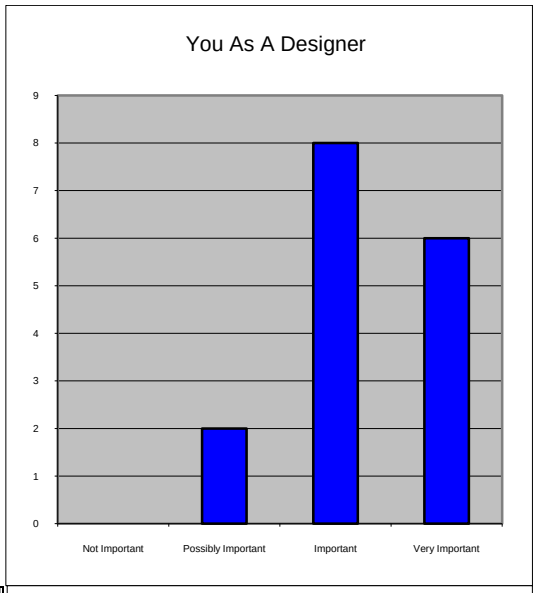


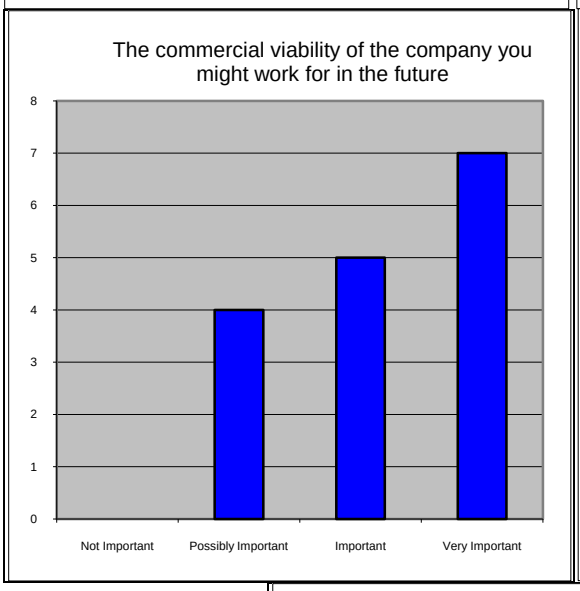


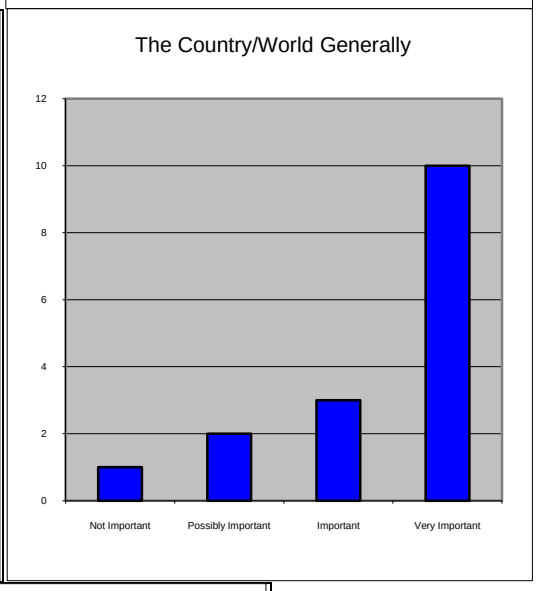


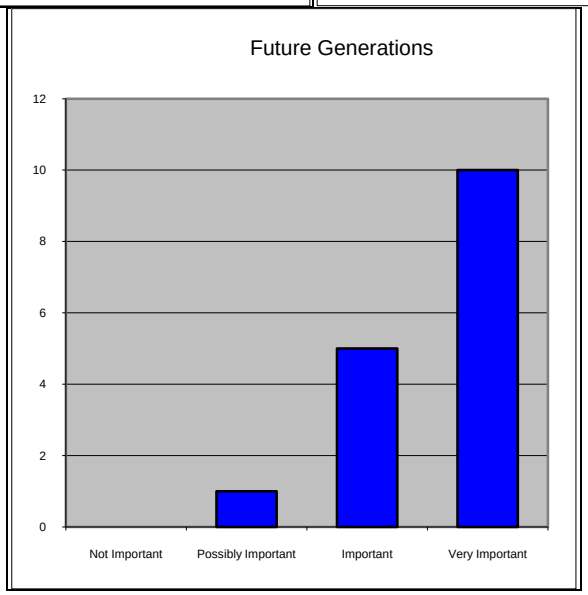
Importance of Sustainable Design and Manufacture?







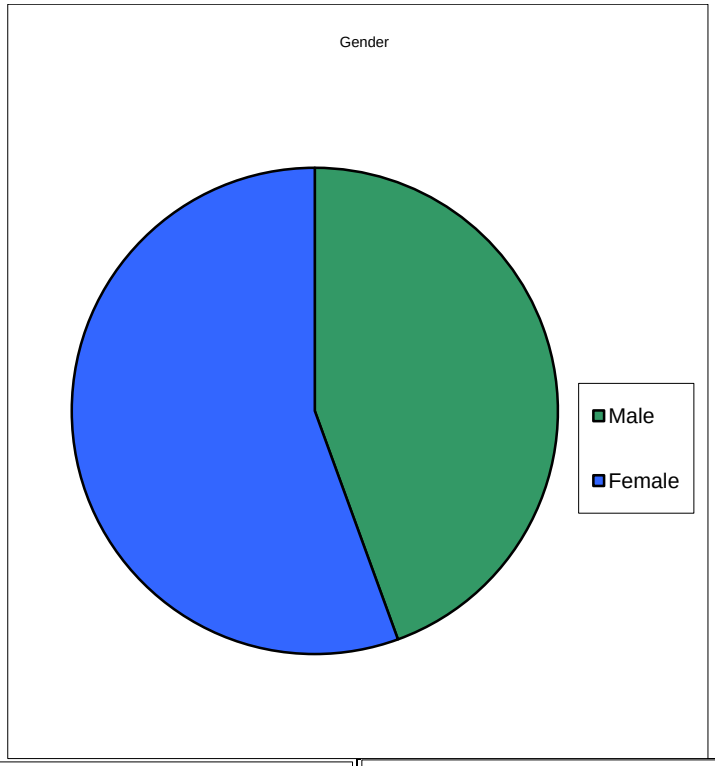


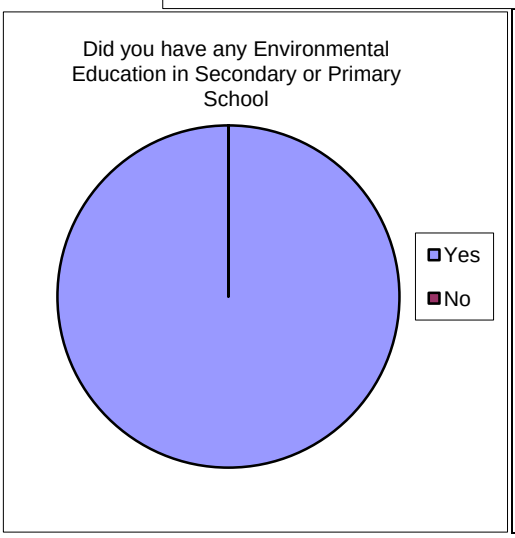


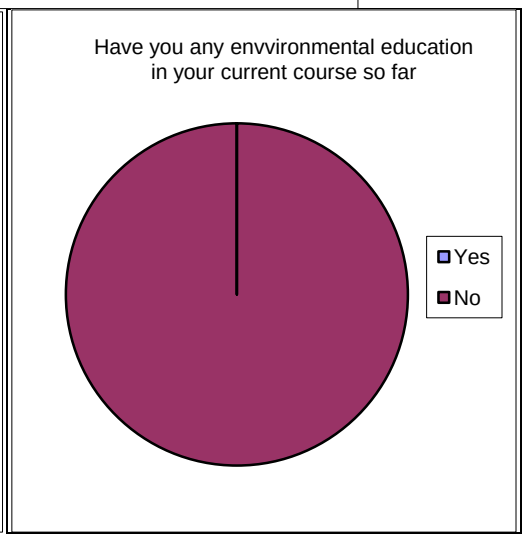
Prior Knowledge Study of 2nd year Industrial Design Students @IT Carlow (2005/06) Raw Data				**9 Students**
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
ISO 14001	7	2	0	0
Kyoto Protocol	6	3	0	0
WEEE	4	4	1	0
Carbon Taxing	5	3	1	0
RhoS	5	3	1	0
Product Take Back Schemes	6	1	2	0
	Male	Female		
Gender	4	5		
			Yes	No
Did you have any Environmental Education in Secondary or Primary School?			9	0
Have you any environmental education in your current course so far?			0	9
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Clean Technology	4	1	4	0
Clean up Technology	4	1	4	0
Eco Labelling	0	4	3	2
LCA (Lifecycle Assessment)	2	6	1	0
Product Lifecycle	0	1	8	0
Waste Minimisation	2	1	6	0
Renewable Energy Technologies	2	1	5	0
Tradable Permits	5	3	1	0
Recycling	0	0	5	4
Reusability	2	5	2	0
Up Cycling	7	2	0	0
Cradle to Grave Design	7	1	1	0
Cradle to Cradle Design	7	1	1	0
EIS (Environmental Impact assessment)	5	2	2	0
Design for Disassembly	1	2	6	0
Producer Responsibility	1	2	2	0
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Acid Rain	0	1	7	1
Air Pollution	0	0	8	1
Solid Waste	0	1	7	1
Carbon Taxing	4	3	1	1
Water Pollution	0	0	8	1
Deforestation	0	0	9	0

Depletion of Natural Resources	0	0	9	0
Desertification	2	2	5	0
Ecosystems	3	1	5	0
Global Warming	1	0	8	0
Ozone Depletion	1	1	7	0
Salinity	6	2	1	0
	Not Important	Possibly Important	Important	Very Important
You Personally	0	2	5	2
You As A Designer	0	1	4	4
The commercial viability of the company you might work for in the future	0	0	5	4
The Country/World Generally	0	1	2	6
Future Generations	0	1	2	6

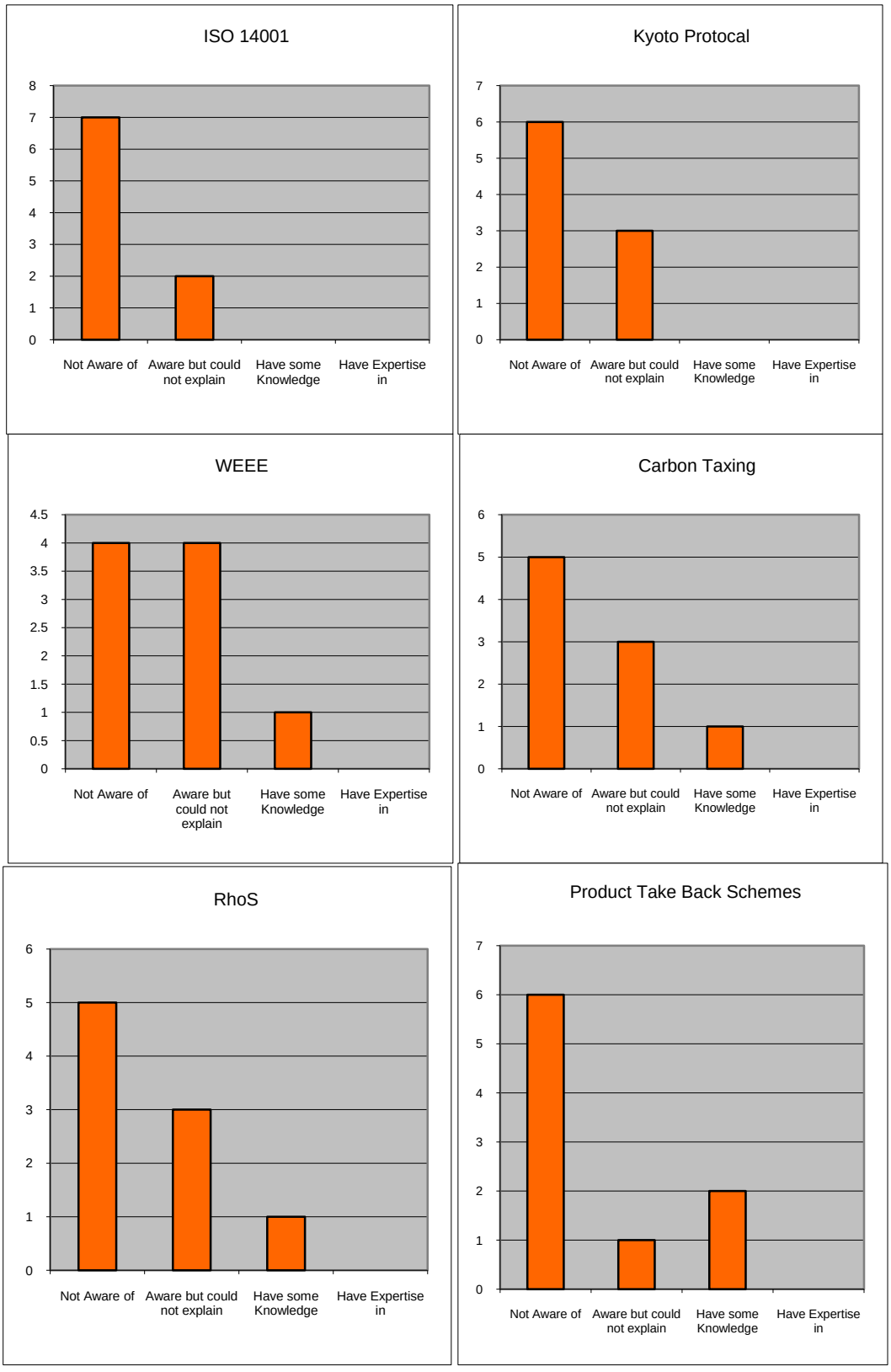
Prior Knowledge Study of 2nd year Industrial Design Students @IT Carlow (2005/06)



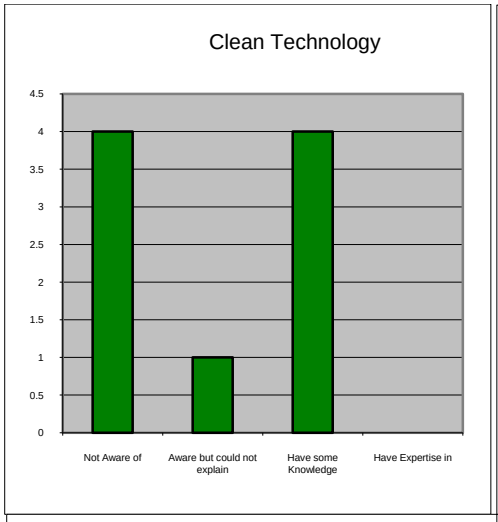


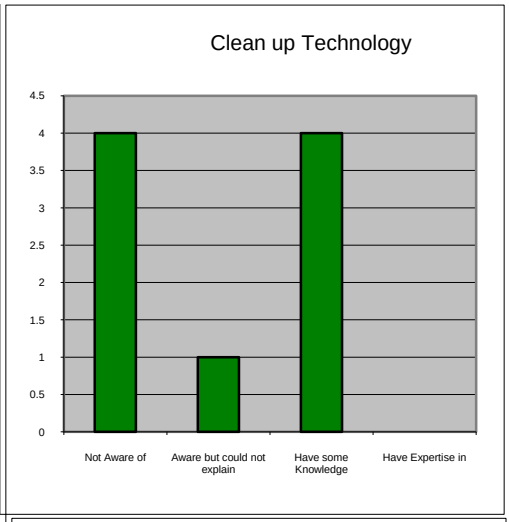


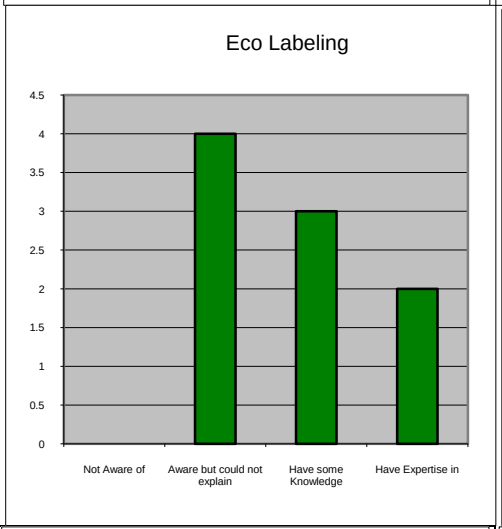
Environmental Legislation, Policy and Standards

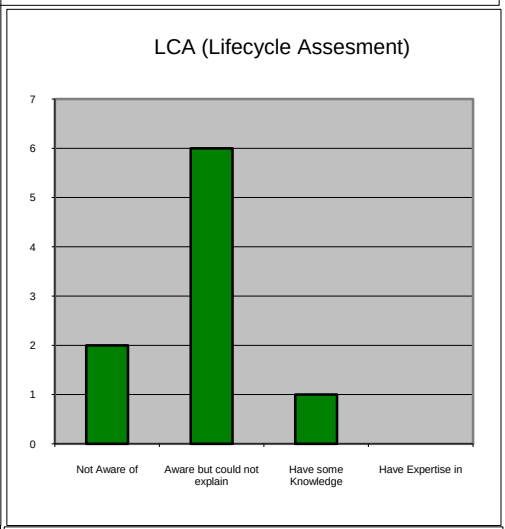


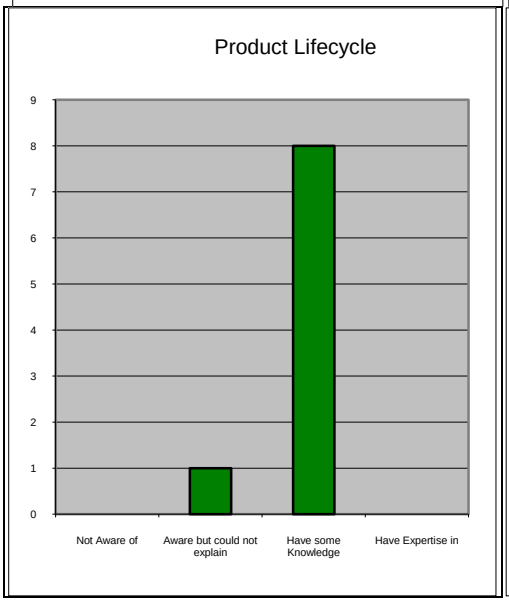
Environmental tools, Technologies and Approaches

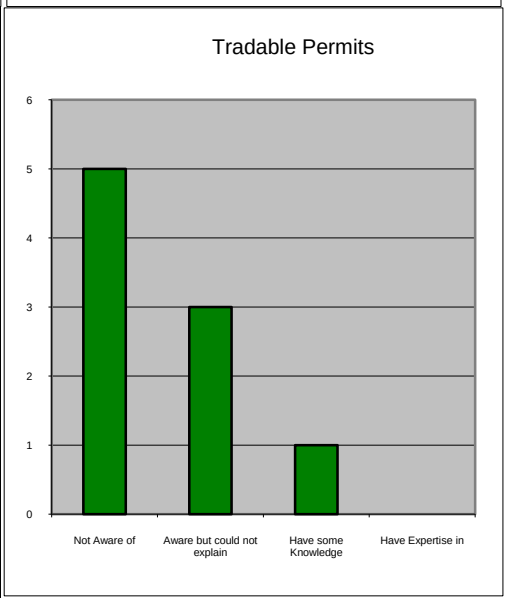




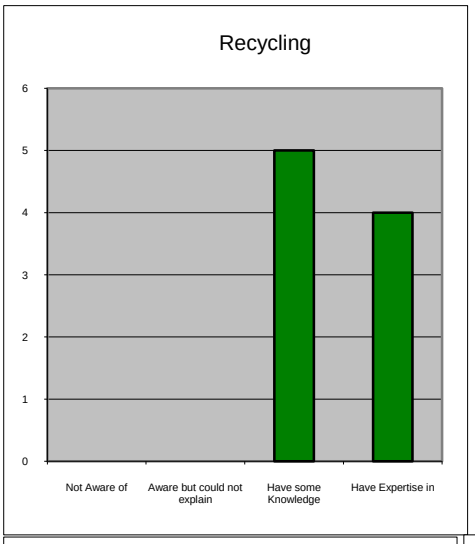


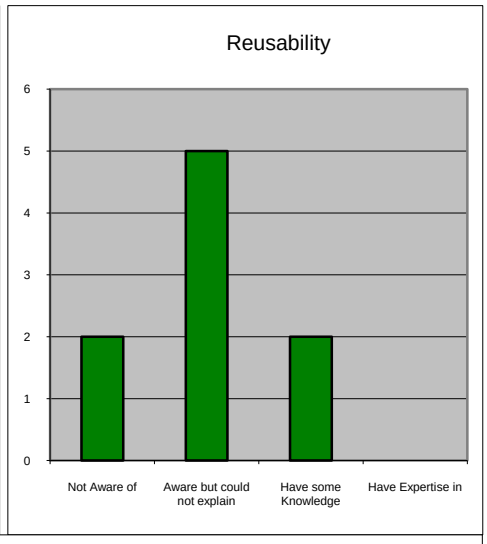


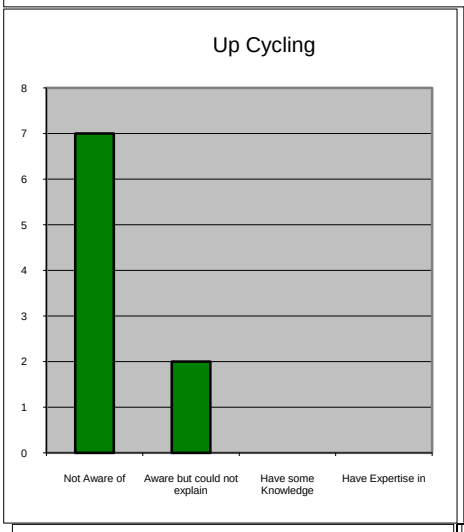


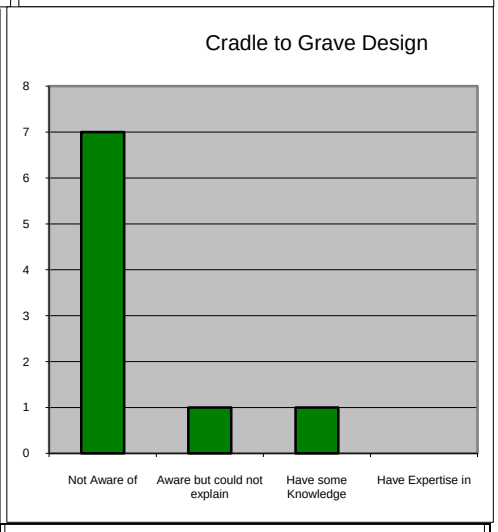


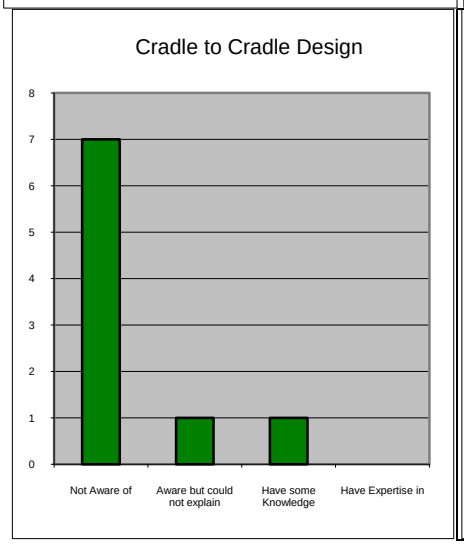
Environmental tools, Technologies and Approaches Contd.

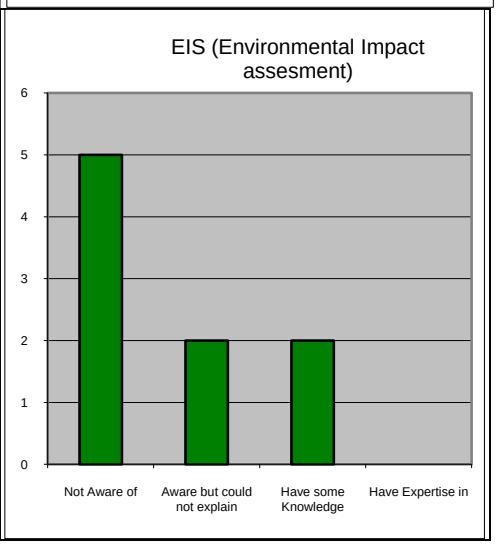


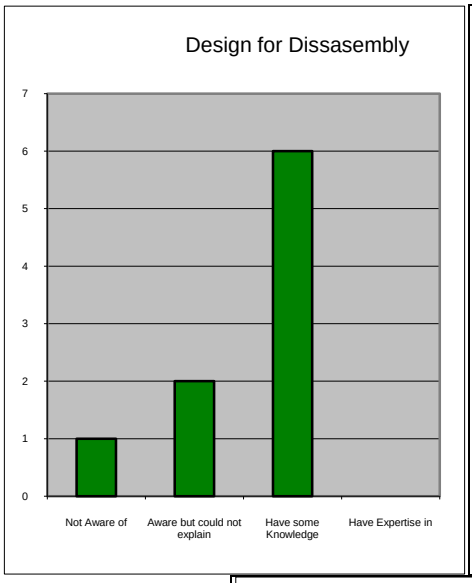


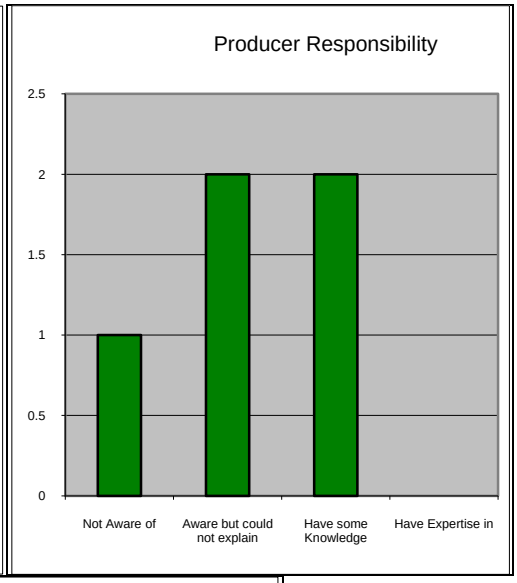


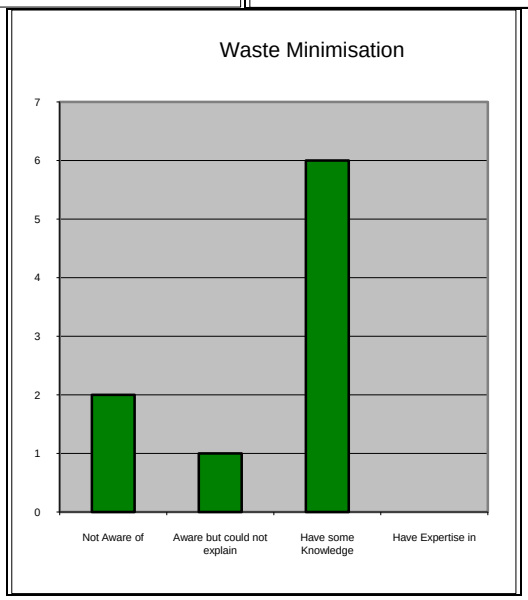




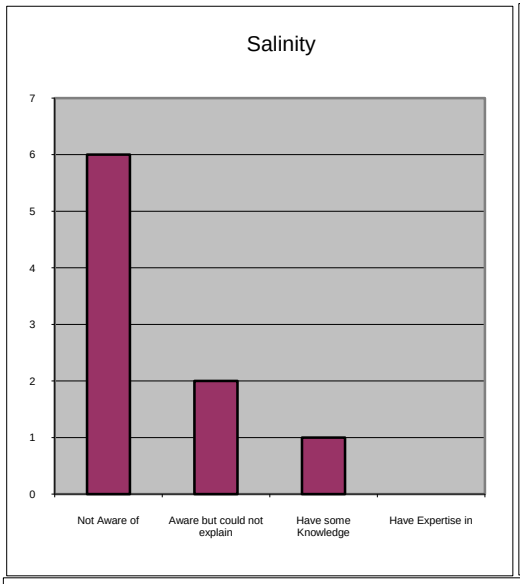


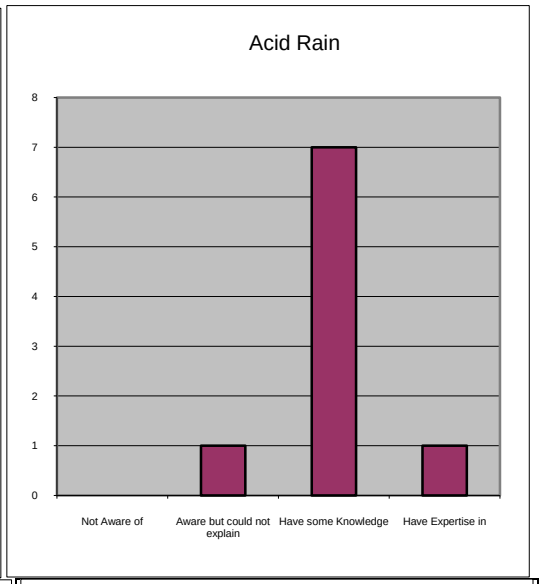

Design for Dissasembly
7
6
5
4
3
2
1
0
Not Aware of
Aware but could not explain
Have some Knowledge
Have Expertise in

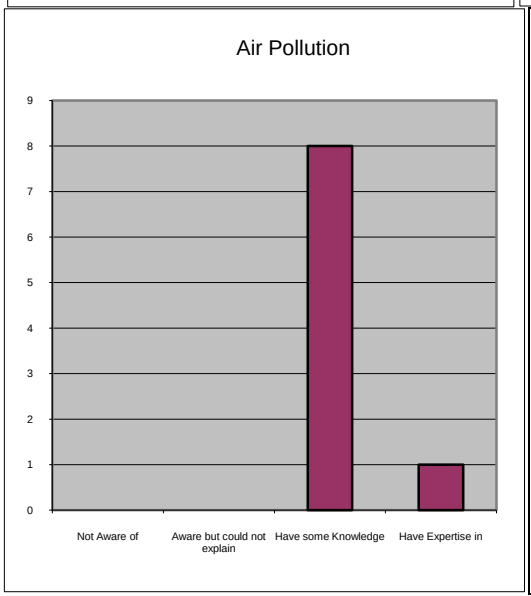

Producer Responsibility
2.5
2
1.5
1
0.5
0
Not Aware of
Aware but could not explain
Have some Knowledge
Have Expertise in

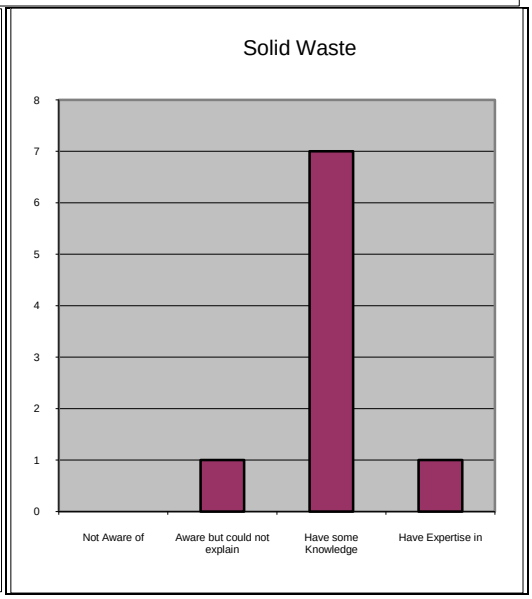

Waste Minimisation
7
6
5
4
3
2
1
0
Not Aware of
Aware but could not explain
Have some Knowledge
Have Expertise in

General Environmental Issues

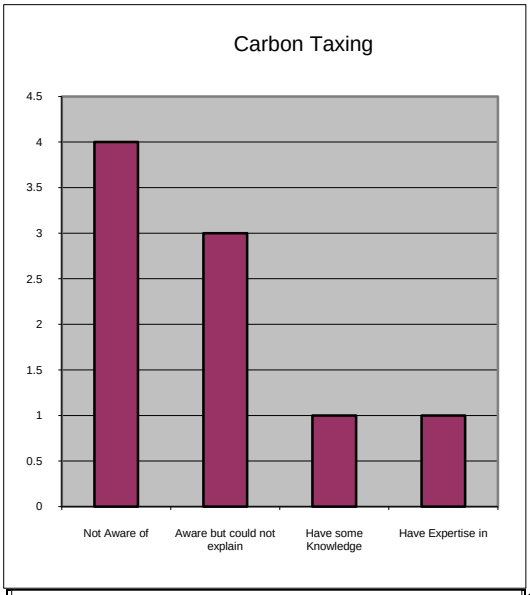


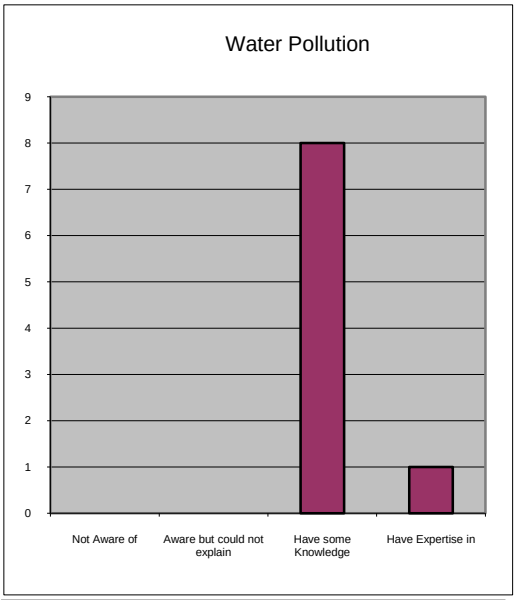


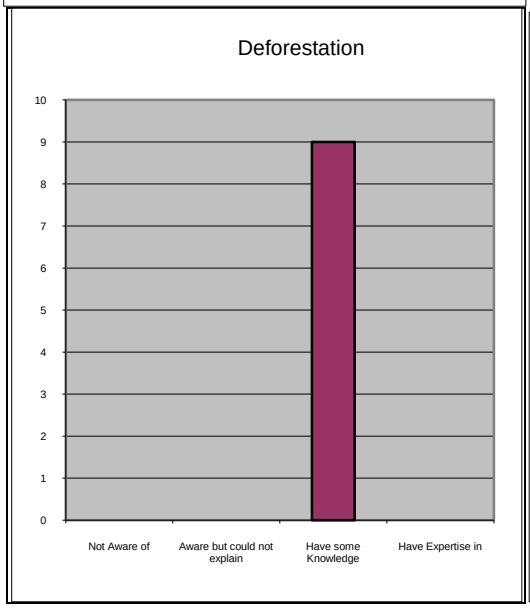


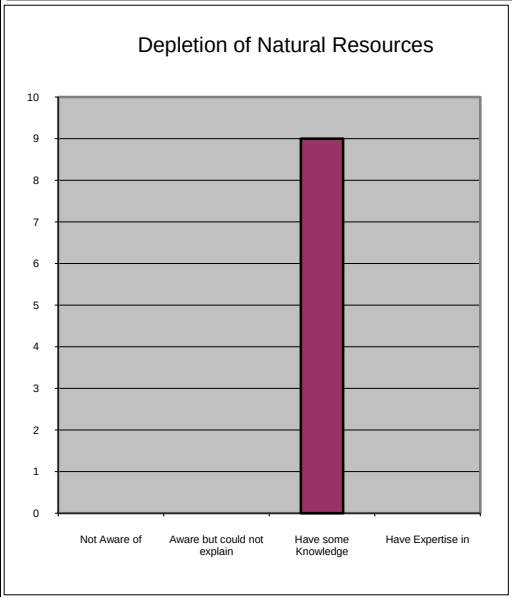


General Environmental Issues Contd.

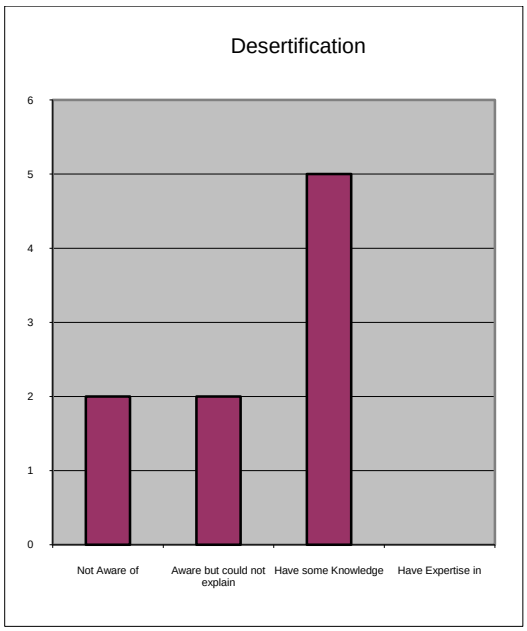


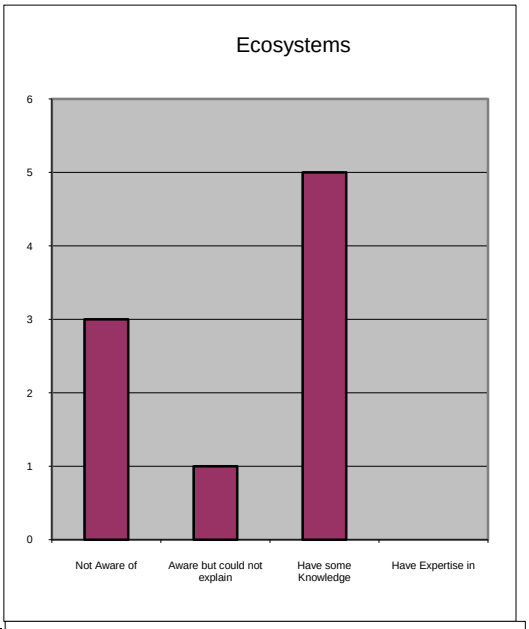


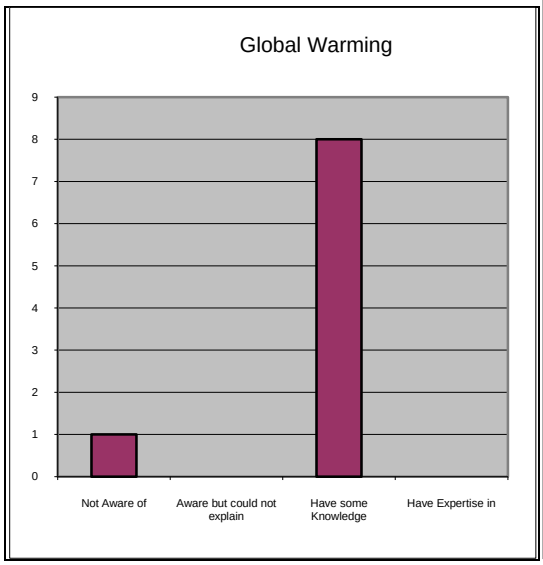


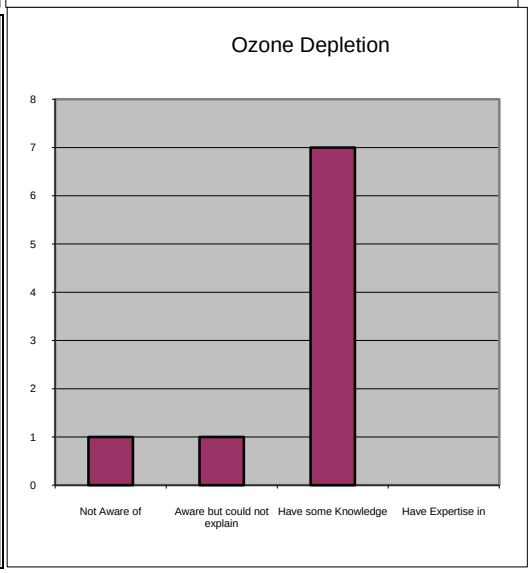


General Environmental Issues Contd.

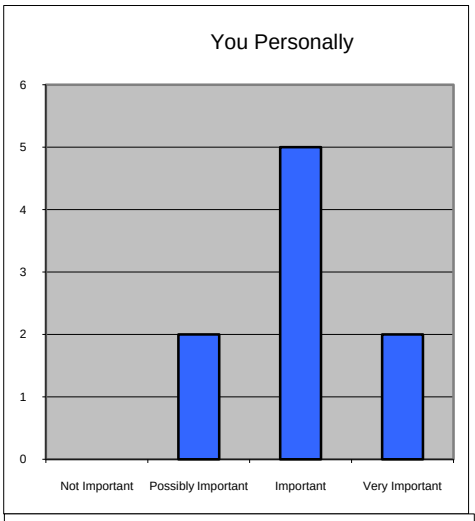


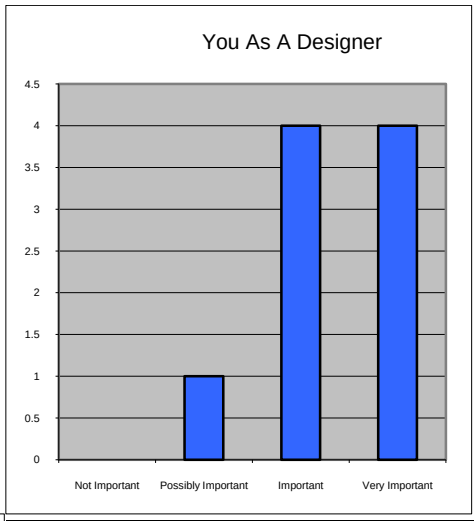


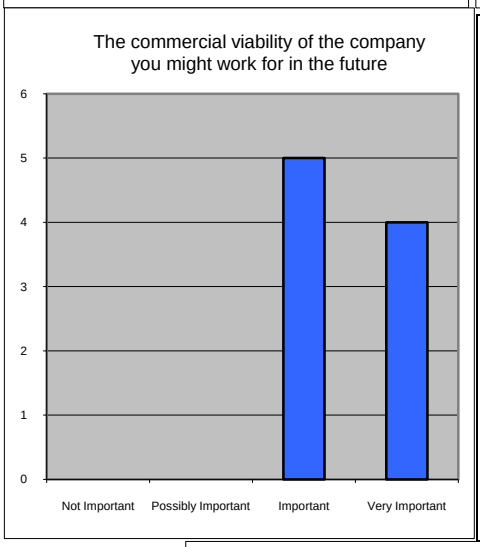


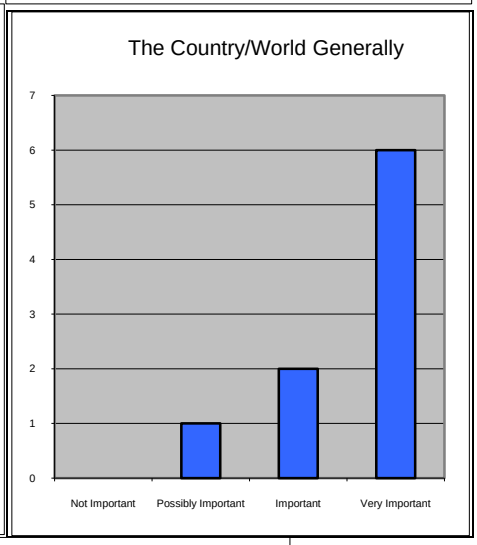


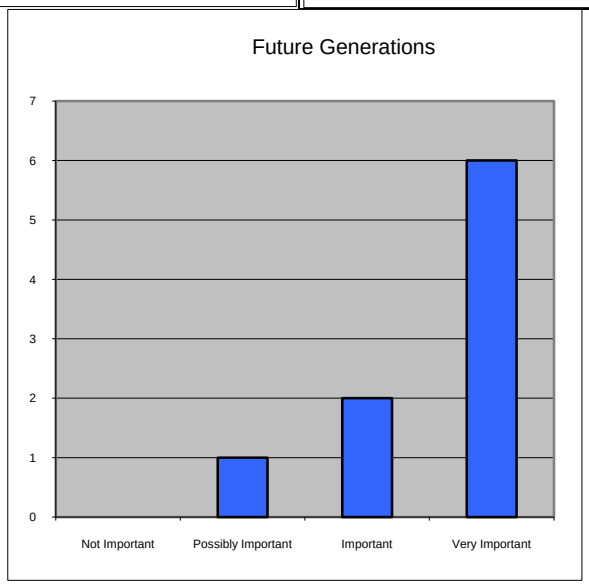
Importance of Sustainable Design/Manufacture for the following







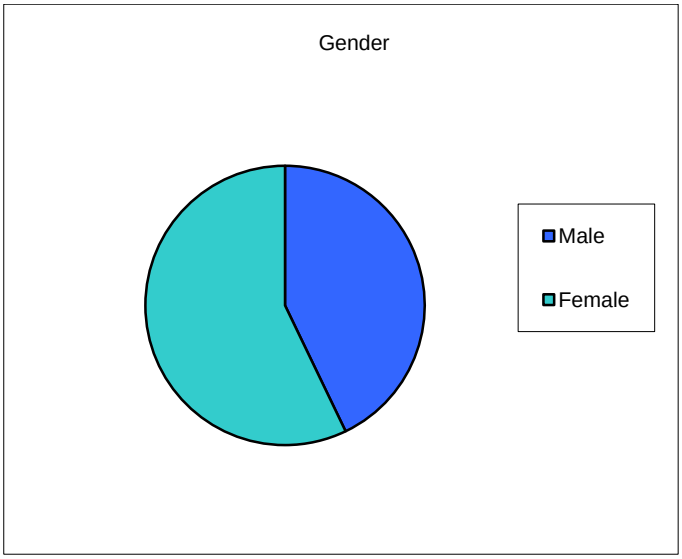


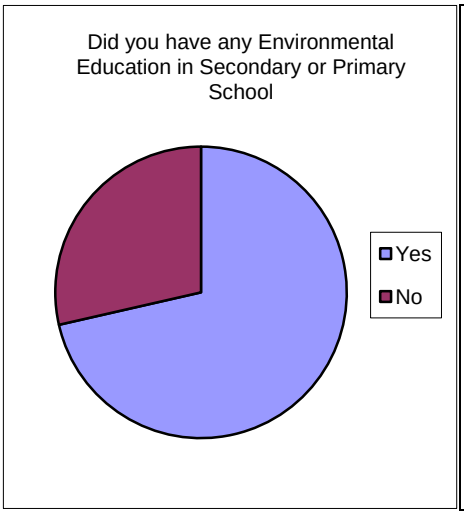


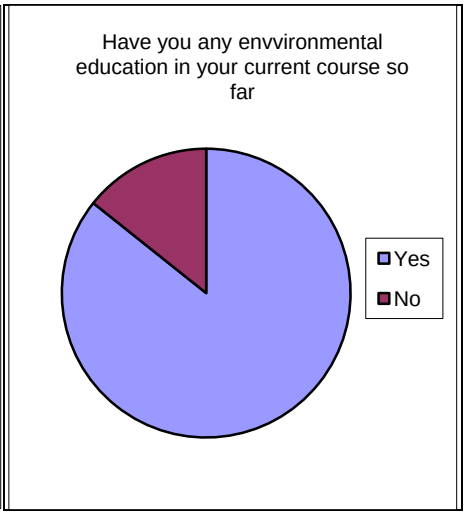
Prior Knowledge Study of 3rd year Industrial Design Students @IT Carlow (2005/06) Raw Data				**7 Students**
	Not Aware	Aware but could not explain	Have some Knowledge	Have Expertise
ISO 14001	5	1	1	0
Kyoto Protocol	4	2	1	0
WEEE	2	2	2	0
Carbon Taxing	1	0	6	0
RhoS	2	5	0	0
Product Take Back Schemes	0	1	6	0
	Male	Female		
Gender	3	4		
			Yes	No
Did you have any Environmental Education in Secondary or Primary School?			5	2
Have you any environmental education in your current course so far?			6	1
	Not Aware	Aware but could not explain	Have some Knowledge	Have Expertise
Clean Technology	4	2	1	0
Clean up Technology	4	2	1	0
Eco Labelling	1	2	4	0
LCA (Lifecycle Assessment)	2	3	2	0
Product Lifecycle	0	0	4	3
Waste Minimisation	0	2	5	0
Renewable Energy Technologies	0	1	4	2
Tradable Permits	6	2	0	0
Recycling	0	0	5	2
Reusability	0	0	5	2
Up Cycling	4	2	1	0
Cradle to Grave Design	0	4	3	0
Cradle to Cradle Design	0	5	2	0
EIS (Environmental Impact assessment)	2	3	2	0
Design for Disassembly	0	2	3	2
Producer Responsibility	0	2	5	0
	Not Aware	Aware but could not explain	Have some Knowledge	Have Expertise
Acid Rain	0	0	6	1
Air Pollution	0	0	6	1
Solid Waste	0	2	5	0
Carbon Taxing	0	3	4	0
Water Pollution	0	0	6	1
Deforestation	0	1	4	2
Depletion of Natural Resources	0	1	6	0
Desertification	1	0	6	0
Ecosystems	0	3	4	0
Global Warming	0	0	5	2
Ozone Depletion	1	0	4	2
Salinity	4	2	1	0
	Not Important	Possibly Important	Important	Very Important
You Personally	0	0	5	2
You As A Designer	0	1	3	3

The commercial viability of the company you might work for in the future	0	0	6	1
The Country/World Generally	0	0	1	6
Future Generations	0	0	0	7

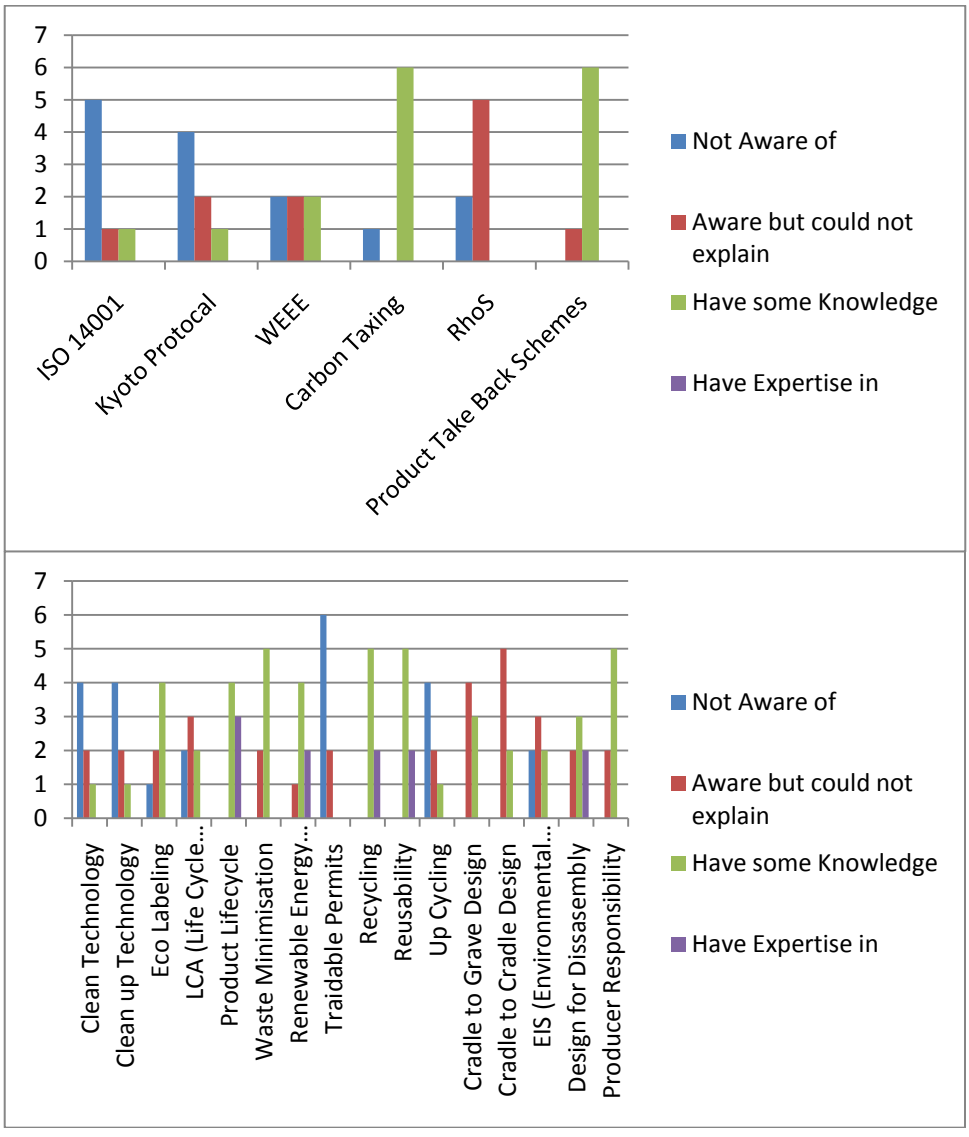
Prior Knowledge Study of 3rd year Industrial Design Students @IT Carlow (2005/06)

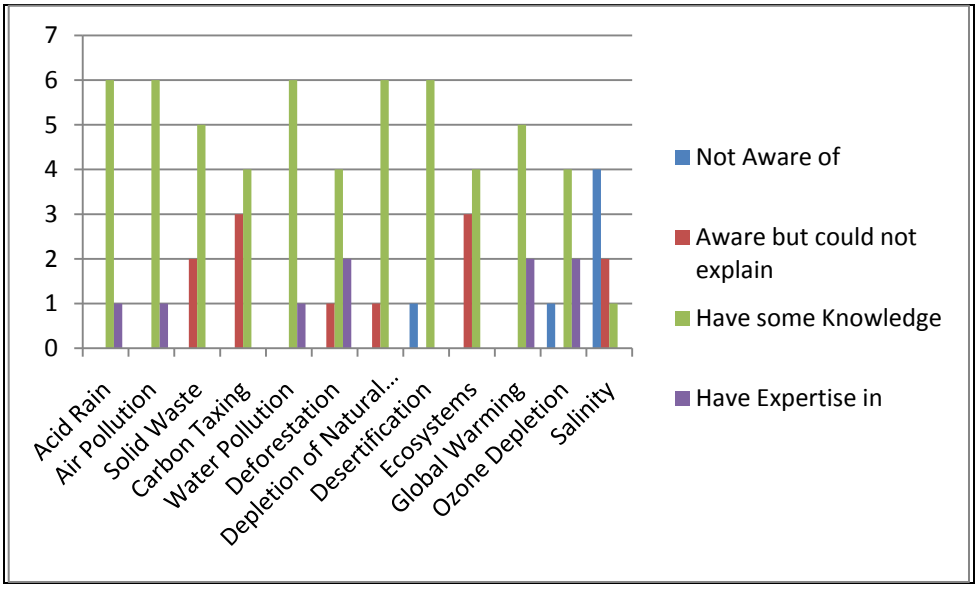






Environmental Legislation, Policy and Standards





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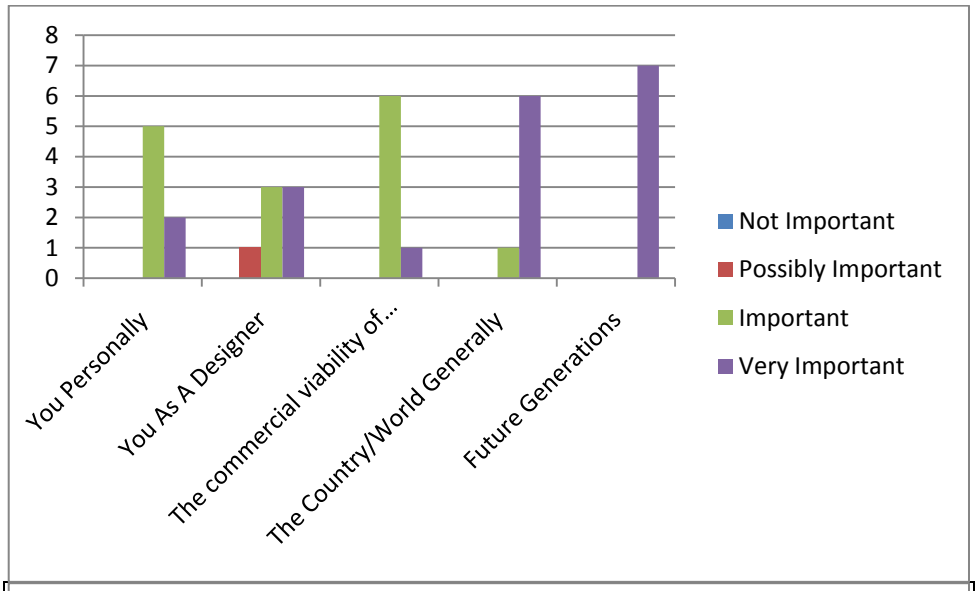

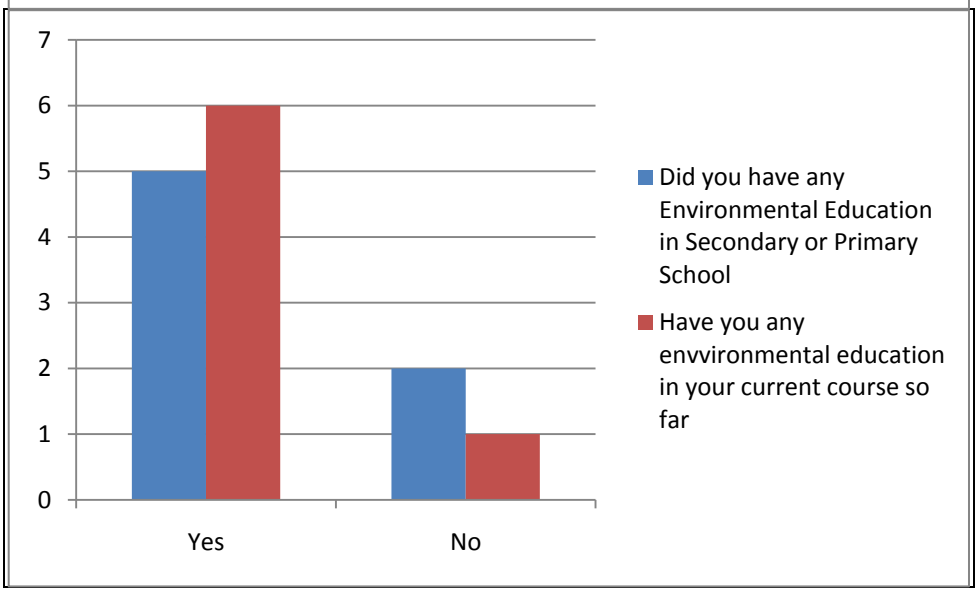

Sustainable Product Design Questionnaire ***Winnovate Companies***

We are asking for your help in assessing your level of understanding in the area of Sustainability and environmental management with respect to your company and your personal experience within your company. The results of this survey will help us customise the Winnovate programme to suit your needs in the coming workshops and will also be used as part of ongoing research on Sustainable Product Design that is being conducted here at the Institute. Your answers will be strictly confidential and will not be used outside the boundaries of the research or the Winnovate programme without your consent.
Please respond to the following items as honestly as possible:

About your company:

Company Name_____

The Companies main area of expertise/ manufacture_____

_____

How long has the company been trading_____

Does your company have an environmental/ sustainability policy? ☐ ☐

Does Environmental legislation affect your companies' activities? ☐ ☐

Does your company have a continuing education practice or policy for its employees? ☐ ☐

About yourself:

Name_____

Position within the company_____

Previous industry experience_____

Educational background (i.e. particular discipline, level)_____

_____

Please indicate your level of awareness in the following areas:

Environmental Legislation, Policy and Standards

	Not Aware	Aware of but could not explain	Have some knowledge	Have Expertise In
ISO 14001	☐	☐	☐	☐
Kyoto Protocol	☐	☐	☐	☐
WEEE (Waste electrical equipment and electronics directive)	☐	☐	☐	☐
Carbon Taxing	☐	☐	☐	☐
RhoS (Restriction of Hazardous Substances directive)	☐	☐	☐	☐
Product take back schemes	☐	☐	☐	☐

Environmental Tools, Technologies and Approaches

	Not Aware	Aware of but could not explain	Have some knowledge	Have Expertise In
Clean Technology	☐	☐	☐	☐
Clean up-Technology	☐	☐	☐	☐
Eco-Labelling	☐	☐	☐	☐
LCA (Life Cycle Assessment)	☐	☐	☐	☐

Product Life Cycle	☐	☐	☐	☐
Waste Minimisation	☐	☐	☐	☐
Renewable Energy Technologies	☐	☐	☐	☐
Tradable Permits	☐	☐	☐	☐
Recycling	☐	☐	☐	☐
Reusability	☐	☐	☐	☐
Up Cycling	☐	☐	☐	☐
Cradle to Grave Design	☐	☐	☐	☐
Cradle to Cradle Design	☐	☐	☐	☐
EIS (Environmental Impact Assessment)	☐	☐	☐	☐
Design for Disassembly	☐	☐	☐	☐
Producer Responsibility	☐	☐	☐	☐

General Environmental Issues

	Not Aware	Aware of but could not explain	Have some knowledge	Have Expertise In
Acid Rain	☐	☐	☐	☐
Air Pollution	☐	☐	☐	☐
Solid Waste	☐	☐	☐	☐

Carbon Taxing	☐	☐	☐	☐
Water Pollution	☐	☐	☐	☐
Deforestation	☐	☐	☐	☐
Depletion of Natural Resources	☐	☐	☐	☐
Desertification	☐	☐	☐	☐
Ecosystems	☐	☐	☐	☐
Global Warming	☐	☐	☐	☐
Ozone Depletion	☐	☐	☐	☐
Salinity	☐	☐	☐	☐

How would you rate the importance of Sustainable Design/Manufacture for the following:

	Not Important	Possibly Important	Important	Very Important
You Personally	☐	☐	☐	☐
Your Company	☐	☐	☐	☐
The Commercial viability of your company	☐	☐	☐	☐
The Country/World Generally	☐	☐	☐	☐
Future Generations	☐	☐	☐	☐

Are their particular areas within your company that you feel could be improved from a sustainability or environmental protection perspective?

Yes ☐ No ☐

If yes please briefly outline the areas_____

_____

_____

_____

_____

_____

Are their particular areas of Product Design Sustainability or Environmental Protection that you would like to see covered in the Winnovate Programme workshops? If so briefly outline

_____

_____

_____

_____

Would you be willing by arrangement to allow a visit to your company to discuss some of the above issues in greater detail?

Yes ☐ No ☐

Thank you for taking the time to fill out the questionnaire.

Prior Knowledge Study of Winnovate SME companies (2005/06) Raw Data			**16 participating Companies**	
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
ISO 14001	10	5	1	0
Kyoto Protocol	9	3	4	0
WEEE	15	0	1	0
Carbon Taxing	10	5	1	0
RhoS	14	1	1	0
Product Take Back Schemes	10	4	2	0
	Male	Female		
Gender	11	6		
			Yes	No
Did you have any Environmental Education in Secondary or Primary School				
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Clean Technology	9	3	4	0
Clean up Technology	12	2	2	0
Eco Labelling	6	7	3	0
LCA (Lifecycle Assessment)	8	5	3	0
Product Lifecycle	2	6	7	1
Waste Minimisation	3	6	6	1
Renewable Energy Technologies	2	6	7	1
Tradable Permits	15	1	0	0
Recycling	0	0	8	8
Reusability	0	2	12	2
Up Cycling	9	7	0	0
Cradle to Grave Design	7	2	4	3
Cradle to Cradle Design	8	1	4	4
EIS (Environmental Impact assessment)	13	1	1	1
Design for Disassembly	9	4	2	1
Producer Responsibility	6	9	1	0
Acid Rain	1	13	2	0
Air Pollution	1	12	3	0
Solid Waste	6	8	2	0
Carbon Taxing	7	0	8	1
Water Pollution	0	1	12	5
Deforestation	0	1	10	5
Depletion of Natural Resources	1	1	13	1
Desertification	5	5	3	3
Ecosystems	2	7	5	2
Global Warming	2	10	4	0
Ozone Depletion	1	3	9	3
Salinity	13	2	1	0
	Not Important	Possibly Important	Important	Very Important
You Personally	0	9	7	0
You As A Designer	0	2	8	6
The commercial viability of the company might work for in the future	0	4	5	7

The Country/World Generally	1	2	3	10
Future Generations	0	1	5	10

Results from16 of 19 SDI students Prior to commencement of Corse in October 2008 (Students are from various professional design backgrounds) Raw Data				
Enviro Legislation Policy and Standards				
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
ISO 14001	10	5	1	0
Kyoto Protocol	3	10	3	0
WEEE	1	7	8	0
Carbon Taxing	2	3	11	0
RhoS	7	6	3	0
Product Take Back Schemes	4	6	6	0
Building Energy Rating (BER)	3	5	7	1
About Your Company				
Type of Company				
			yes	**no**
Does your Company have a Sustainability Policy?			2	14
Does Enviro Legislation affect your company's activities?			8	5
Continuing Education Policy			7	7
Gender			4Female	12 Male
Enviro Tools, Technologies and Approach				
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Clean Technology	7	5	4	0
Clean up Technology	9	4	3	0
Eco Labelling	1	6	9	0
LCA (Lifecycle Assessment)	3	7	6	0
Product Lifecycle	1	4	8	2
Waste Minimisation	2	5	7	2
Renewable Energy Technologies	6	8	2	0
Tradable Permits	9	7	0	0
Recycling	0	1	12	3
Reusability	1	3	9	3
Up Cycling	9	3	2	2
Cradle to Grave Design	5	6	3	2
Cradle to Cradle Design	9	0	5	2
EIS (Environmental Impact assessment)	5	5	5	1
Design for Disassembly	4	2	8	2
Producer Responsibility	4	4	6	2
General Environmental Issues				
	Not Aware of	Aware but could not explain	Have some Knowledge	Have Expertise in
Acid Rain	0	6	10	0
Air Pollution	0	5	11	0

Solid Waste	2	5	7	1
Carbon Taxing	1	7	7	0
Water Pollution	0	5	8	2
Deforestation	1	5	9	0
Depletion of Natural Resources	0	3	11	1
Desertification	5	3	7	0
Ecosystems	1	8	6	0
Climate Change	0	3	11	1
Ozone Depletion	0	5	9	1
Salinity	9	4	2	0
Rating the Importance of SD and Manufacture				
	Not Important	Possibly Important	Important	Very Important
You Personally	0	1	6	8
Your Company	0	1	6	8
Company Viability	0	2	7	6
The Country/World Generally	0	0	2	13
Future Generations	0	0	1	14

Appendix B. Graduate Interview Questionnaire

Graduate Interview Questions (Note: the responses to these questions are in digital audio format and available from the researcher. To maintain confidentiality of interviewees it was decided not to place them in the thesis appendix)

Interview Questions for Graduates 2007

The Research being conducted is in the context of a PhD study of 'Sustainable Design Education'. The answers to the questions below will remain confidential and specific comments made will only be used in the final thesis with the consent of the interviewee and their employer.

The Questions below are a proposed list of questions to be put to the interviewee in an oral interview which will be recorded.

Personal Questions (For you as a designer)

1. Employability, how did you get the job?
2. Can you describe the work you do and how it fits in to the company's strengths?
3. Did the specifics of you major project/portfolio influence your employment?
4. What is your current thinking/understanding about sustainable design?
5. Does the fact that you studied Sustainable Design as part of your course influence your decision making with respect to the work you currently do?
6. Is (CSR) Corporate Social Responsibility something that you are aware of?
7. Has your perspective changed with time (the idealism of being a student V the realism of employment and dealing with clients/employer)
8. Are there other skills that were key in terms of what your company were looking for in a graduate?

Questions Related to your Employer/Company

9. Can you describe the attitude of your employer towards sustainability, if any?
10. Is there a notion of Product LCT (Life Cycle Thinking) in the design work that you are involved with.
11. Are you aware of Legislative pressures/ opportunities with respect to your companies work
12. How does your company approach NPD (New Product Development),
13. Is local manufacture a priority for your company, Is Local procurement an issue (for components or services?
14. Is Sustainability a priority in your companies work?
15. Is Sustainability identified as a concern for your customers?
16. Do you or your company see Sustainability as a tool for Commercial advantage?

Adam de Eyto (IT Carlow (Design)/ Bournemouth University (DEC))
Contact: deeytoa@itcarlow.ie Tel 059 9170465 or 087 6868564

Appendix C. SDI Course Outlines and HETAC Validation Documentation

Certificate in Sustainable Design Innovation (Level 9)

Introduction:
Primarily this course aims to up skill practicing design professionals in the area of Sustainable Design Practice (SDP). Likely students on this program would typically be designers, architects, design managers, marketing managers and other business managers with responsibility for new product development (NPD), company strategy and design. Those interested in developing capacity in sustainable design and innovation as a business opportunity would also benefit from this programme.

Endorsments from past students:
"*SDI helped to give me the capacity to address and implement sustainable design within our practice*"- Norman Stevenson
(Senior Industrial Designer with Design Partners)

"The SDI course gave me the time, structure and learning environment to reach a far greater strategic and tactical understanding of the issues, challenges and opportunities to respond to global climate and sustainability"- Paul O'Connor (Architect)

This course is an ECTS 10 credit (Masters) Level 9 module.
Entry Requirements:
The following applicants will be considered for entry:
Mature students (23 years or over)
Honors (Level 8) Degree in a Design discipline or similar or an appropriate level of prior experiential learning.
Other applicants will be considered on a case by case basis

Programme Content:

- Introduction to Sustainable Design (SD), case studies, approaches and philosophies
- Practical sustainable design strategies for designers
- Social and environmental legislative concerns for designers
- LCA (Product Life Cycle Analysis), LCA tools, IT(Information Technology) packages, simplified applied LCA
- Social and Corporate Responsibility
- Packaging and waste considerations for designers
- Marketing sustainable design
- Communication and presentation of sustainable design and business
- Development of the SD Brief and SD Strategy
- SD Facilitation and Multidisciplinary collaboration
- Procurement and specification of materials and processes
- Sustainable Product Service Systems (SPSS)

Progression Opportunities:
Graduates will be eligible for exemptions on the proposed MBA in Technology Management.
Duration:
15 weeks-proposed for Saturdays 10am-1pm (Run every second Saturday)
10 x 3 hour workshop/lectures/mentoring sessions and independent applied research project (with remote mentoring)
Starting Date: September 2009
Fee details: €1200

Awarded by
Institute of Technology, Carlow

In association with:

designcore tomorrow's design TEPUI design ireland SKILLNETS cultivate living and learning centre

Module Title	**Sustainable Design Innovation**				
Mandatory/ Elective	Elective	**ECTS Credit Rating**	10	**Module Level (NFQ)**	9

Module Aim

The module aims to up skill graduate business and design professionals in the area of Sustainable Design Innovation (SDI). The module aims to develop the broad understanding of the students towards the complexities of Sustainable Design (SD) and also to provide them with practical SD tools and strategies for implementation in their business.

Learning Outcomes

On completion of this module a learner should be able to;

LO1. Re-assess their (and their business') core competency from a sustainable design and management perspective.

LO2. Identify sustainable design and sustainable new product opportunities at multiple strategy levels for implementation in to their daily practice.

LO3. Understand and apply Lifecycle Thinking (LCT) in their design work and business strategy

LO4. Use SDP as a tool for competitive advantage within their design business and as a wider business and marketing tool

LO5. Use the exemplar project developed through the module as a template for further SD initiatives in their work.

LO6. Show transformational leadership in a design and business context

LO7. Enable the development of a knowledge and skills network for future learning support in sustainable design, business and technology management.

Module Content

The Module will include the following elements

Introduction to sustainable design, case studies ,approaches and philosophies. 8.33%

Practical sustainable design strategies for designers and managers. 8.33%

Social and environmental legislative concerns for designers and

mananagers 8.33% LCA (Product Life Cycle Analysis), LCA tools, IT (Information Technology) packages, simplified applied LCA. 8.33% Social and Corporate Responsibility (CSR). 8.33% Packaging and waste considerations for designers. 8.33% Marketing sustainable design. 8.33% Communication and presentation of sustainable design and business. 8.33% Development of the SD Brief and SD Strategy. 8.33% SD Facilitation and Multidisciplinary collaboration. 8.33% Procurement and specification of materials and processes. 8.33% Sustainable Product Service Systems. 8.33%

NFQ Programme(s) Link(s)

Masters in Business Administration

Pre-Requisite(s)

Honours (Level 8) Degree or an appropriate level of prior experiential learning

Co-Requisite(s)

None

Teaching and Learning Strategies

The module will be delivered with a combination of workshop and theoretical taught elements. Programme delivery will be aided by web enabled learning and a development of a web based resource for networking and communication (Blackboard discussion boards, course reading and relevant web reading/viewing).Specialist local and international industry experts would deliver discipline specific elements through case studies and theory, Broader SD learning would be explored through small group work and applied research related to their design or business practice with mentoring from the course lecturers/facilitators.

Continuous Assessment of project through the applied research related to learners' design or business practice. A Guideline Marking scheme for assessment would be as follows: Development of Personal Project Brief 30% Engagement in collaborative peer review work 10% Presentation of Final Personal Project 60%

				Full-time	36
Delivery Schedule				*Other*	214
				Workload	250 hours including Independent Learning
Assessment	CA	Proj	Prac	Final	Total
Breakdown	40	60			100

Bibliography Essential and Recommended Texts and/or materials required. Web referen as appropriate

Essential reading:

Benyus, Jane, M, 2003, *Biomimicry-Innovation Inspired by Nature,* Harper Collins.

Bjamra,T and Lofthouse,V 2007, *Design for Sustainability -A Practical Approach*, Gower Publishing Ltd.

Fuad-Luke, A, 2007, *Eco-Design Handbook*, London; Thames and Hudson.

Lewis,H, and Gertsakis,J, with Grant,T, Morelli, N, and Sweatman,A, 2001, *Design + Environment, a global guide to designing greener goods*, Sheffield: Greenleaf Publishing.

Mc Donnagh, M, and Braungart, M, 2002, *Cradle to Cradle, Remaking the way we make things,* New York*:* North Point Press.

Papanek, V, 1971, *Design for the Real World, Human Ecology and Social Change*, London: Thames and Hudson.

Papanek, V, 1995, *The Green Imperative, Ecology and Ethics in Design and Architecture*, London: Thames and Hudson

Richardson J, Irwin,T andDherwin C, 2005, *Design and Sustainability-A Scoping Report* for the Sustainable Design Forum, Design Council, London.

Rhea, D, 2003, *Bringing Clarity to the Fuzzy Front End, A predictable process for Innovation* In Laurel, B. (ed.) *Design Research,* MIT Press.

Granta Design, 2007, *Cambridge Engineering Selector*

software supplier, http://www.grantadesign.com (accessed 12/3/08).

Recommended reading/Viewing

Burtynsky, E, 2007, Manufactured Landscapes,DVD, 83 mins, ASIN**:** B001BOA2L6

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Appendix D. SDI Feedback Data and Questionnaires

Design Ireland Skillnet formal feedback (sought mid way through SDI course January 2009)

QuestBack export
Certificate in Sustainable Design: Course Evaluation

17 responses (17 unique)

		Response	Percent	Mean
Q1	**I understood the course objectives well**	17		4,00
	1(Strongly Disagree)	1	5.9 %	
	2(Disagree)	2	11.8 %	
	3(Neither Agree nor Disagree)	0	0.0 %	
	4(Agree)	7	41.2 %	
	5(Strongly Agree)	7	41.2 %	
Q2	**The objectives of the course as I understand them were met**	17		3,88
	1	1	5.9 %	
	2	2	11.8 %	
	3	2	11.8 %	
	4	5	29.4 %	
	5	7	41.2 %	
Q3	**The information was clearly presented**	17		4,18
	1	0	0.0 %	
	2	2	11.8 %	
	3	2	11.8 %	
	4	4	23.5 %	
	5	9	52.9 %	
Q4	**There was enough time for the training**	17		3,59
	1	0	0.0 %	
	2	4	23.5 %	
	3	3	17.6 %	
	4	6	35.3 %	
	5	4	23.5 %	
Q5	**The trainer helped me to learn**	17		4,06
	1	0	0.0 %	
	2	1	5.9 %	
	3	3	17.6 %	
	4	7	41.2 %	
	5	6	35.3 %	

Q6	**I am satisfied that I can apply what I learned to my job**	17		4,06
	1	0	0.0 %	
	2	2	11.8 %	
	3	4	23.5 %	
	4	2	11.8 %	
	5	9	52.9 %	
Q7	**Overall the training was beneficial to me**	17		4,12
	1	1	5.9 %	
	2	1	5.9 %	
	3	3	17.6 %	
	4	2	11.8 %	
	5	10	58.8 %	
Q8	**What is your age range?**	16		3,00
	<21	0	0.0 %	
	21-30	5	31.3 %	
	31-40	7	43.8 %	
	41-50	3	18.8 %	
	51-60	1	6.3 %	
	>60	0	0.0 %	
Q9	**Please indicate gender**	16		1,25
	Male	12	75.0 %	
	Female	4	25.0 %	
Q10	**What job title best describes your position?**	16		5,56
	Senior Manager/Owner Manager	5	31.3 %	
	Middle Manager	2	12.5 %	
	First Line Supervisor	0	0.0 %	
	Production Employee	0	0.0 %	
	Professional (except IT staff)	2	12.5 %	
	Clerical admin employee	0	0.0 %	
	Customer Service employee	0	0.0 %	
	Sales employee	0	0.0 %	
	IT staff	0	0.0 %	
	Other, please specify	7	43.8 %	
Q11	**What is the highest educational qualification you have received to date?**	16		6,13
	Primary	1	6.3 %	
	Junior Certificate	0	0.0 %	
	Leaving Certificate	0	0.0 %	
	Certificate	0	0.0 %	
	Diploma	1	6.3 %	
	Primary Degree	8	50.0 %	

Post Graduate Degree	4	25.0 %
Other, please specify	2	12.5 %

Institute of Technology Carlow
Sustainable Design Innovation

Participant End Feedback Sheet

Did the course live up to your expectations?

Yes ☐ No ☐

Why, or why not?

Do you feel more enabled by your participation on the course?

Yes ☐ No ☐

In what way(s)?

_____

Are there particular elements of the course that you feel need to be changed? If so, please describe:

_____
_____
_____
_____
_____
_____

Is there anything you feel needs to be added to the course?

_____
_____
_____
_____
_____
_____
_____
_____

Please rate the quality of the following: (1-Poor, 5- Excellent)

Course delivery (Lectures) ☐

Course Facilitation ☐

You're Experience of dealing with IT Carlow ☐

The structure of the course ☐

Would you be interested in a Full Masters Program in the sustainable design field if it became available?

Yes ☐ No ☐

If you would like to endorse the course please write a short comment below to recommend it to future participants: (This will be used for course advertising or feedback to Skillnet/ IT Carlow only with your signed permission and will be accredited to you and your company)

_____
_____
_____

Permission: *Signed:* *Date:*

Sustainable Design Innovation 08/09 End Participant Feedback Results

14 of 19 participants filled out sheet

Did the Course Live up to your Expectations?

Yes No

Comments

- Actually better than I had expected. Great external speakers on a diverse range of topics
- Covered such a broad range of topics issues
- Exceeded Expectations
- Multidisciplinary, Broad Ranging, Relevant, Well communicated
- Overview + Detail\ Broad design spectrums
- Huge amount of information and Knowledge learned
- It Exceeded them, Extremely thought provoking
- It opened my mind to Sustainable Design
- I feel I learned more than I expected to from the different design fields
- Exceeded Expectations
- It was much better
- It has given me a foundation to build on with regard to sustainable design, Theory and practice

Do you feel more enabled by your participation on the course?

Yes No

In What Ways?

- Better understanding of the scope of Sustainable Design, Resources
- Knowledge to improve my work, great network
- Knowledge, Action plans, encouragement
- I know more about sustainability and what it really means
- More Knowledgeable
- The Course has given me a philosophical view of the big picture
- It has broadened my horizons on all things sustainable
- Knowledge to apply to our business and my living
- Greater strategic and technical understanding of sustainability issues
- Enabled me to ask better questions and look deeper
- I feel knowledge is power, more concentrated focus
- Greater level of knowledge of sustainable design innovation

Are there particular elements of the course that you feel need to be changed? If so please describe

- Presentation of projects on final day was too rushed- Would require 2 days (continued… see original)
- From a product design point of view a lecture specifically on materials would be good, otherwise there is little I would change
- Group discussions needed some moderation, they were a good element but could easily lose focus
- Introduce (or bring) projects at an earlier stage. Track evolution or 're-volution' of the project against

lecture information

- It could be made longer
- Small point (More work on ideas)not so much the bigger ideology, Become drivers, "Proof is in the pudding!"
- It is very condensed- A full day would be more practical
- Tuition on LCA modelling- Computer Labs (Could be a module)
- I would like a bit more focus on materials analysis and graphic design

Is there anything you feel needs to be added to the course

- I would like the CES Cambridge material selector programme to be available. I would like the chance to meet up with the class once the course is over to form a sustainable design group
- More
- Irish Lecturers: Are there people in Ireland that can contribute!
- LCA tool Training!!!
- Follow up on projects as discussed on presentation day, Events that may connect on a social level- extend events dealing with management-lecture from a management person
- Just more time, less focus on projects- maybe only half an hour per session, a quick catch up
- Time! 3 Hours every 2 weeks is too short, Continuous Assessment (by Peers?) by posting reflections on Blackboard immediately following each lecture
- No!
- As Above
- The level of speakers was V Good- The theory is vital- (Long comment form Patrick Shaffery, see original) refers to future promotion and awareness of course (useful ideas here)

Please Rate the Following (1-Poor, 5-Excelent)

	1		3	4	5
Course Delivery (Lectures)				3	11
Course Facilitation				3	11
Your Experience of Dealing with IT Carlow			1	4	9
The Structure of the Course				5	9

Would you be interested in a Full Masters Program in the Sustainable Design Field if it became available?

Yes No (Some cited time concerns

If you would like to endorse the course please write a short comment below to recommend it to future participants (This will be used for course advertising or feedback to Skillets/IT Carlow only with yours signed permission and will be accredited to you and your company)

I found the course to be very enjoyable, with great international speakers on a diverse range of subjects - John Walsh (Furniture designer with MADE)

This course has provided me with the perfect introduction to sustainable design - it has whet the appetite and fed the mind - Alan Conlan (Graphic Designer with RRD)

Can't recommend this course enough! Inspirational and I already know some of my friends are coming!! - Vincent Mc Grath (Furniture designer with Sheila Moore Ltd.)

This course is not about the plethora of 'Post -It' type solutions available today, It is about fundamental philosophy and knowledge to see through the volumes of misinformation and dubious solutions used to 'Greenwash' products , processes and companies, Outstanding - David Mavroudis (Architect)

There are so many buzz words around sustainability these days. A course like this goes back to first principles and gives foundation to an understanding of what they actually mean and represent. Putting the theory into practice is the place that a course like this can be a catalyst for any person across different disciplines - Patrick Shaffery (Architect)

I learned far more in the 6 months of this course about sustainability than I ever envisaged. I feel that this course has helped me become a more responsible designer and has been a great benefit to me personally. I highly recommend it- Gemma Shore (Graphic/Packaging Designer with Jivo)

I would highly recommend any one working in design or have an interest in sustainability to take this course. It was well run and organised - Loretta McDonnagh (Interior Designer)

It opened my eyes to many obstacles that have to be overcome but showed me the strategies and pathways to overcome them - Bernadette Douglas (Industrial Designer)

Sustainability is happening + Designers must come to terms with this and restructure their design ethic and process. Great starter on Sustainable Design - John O'Shea (Product Design Engineer with ABS)

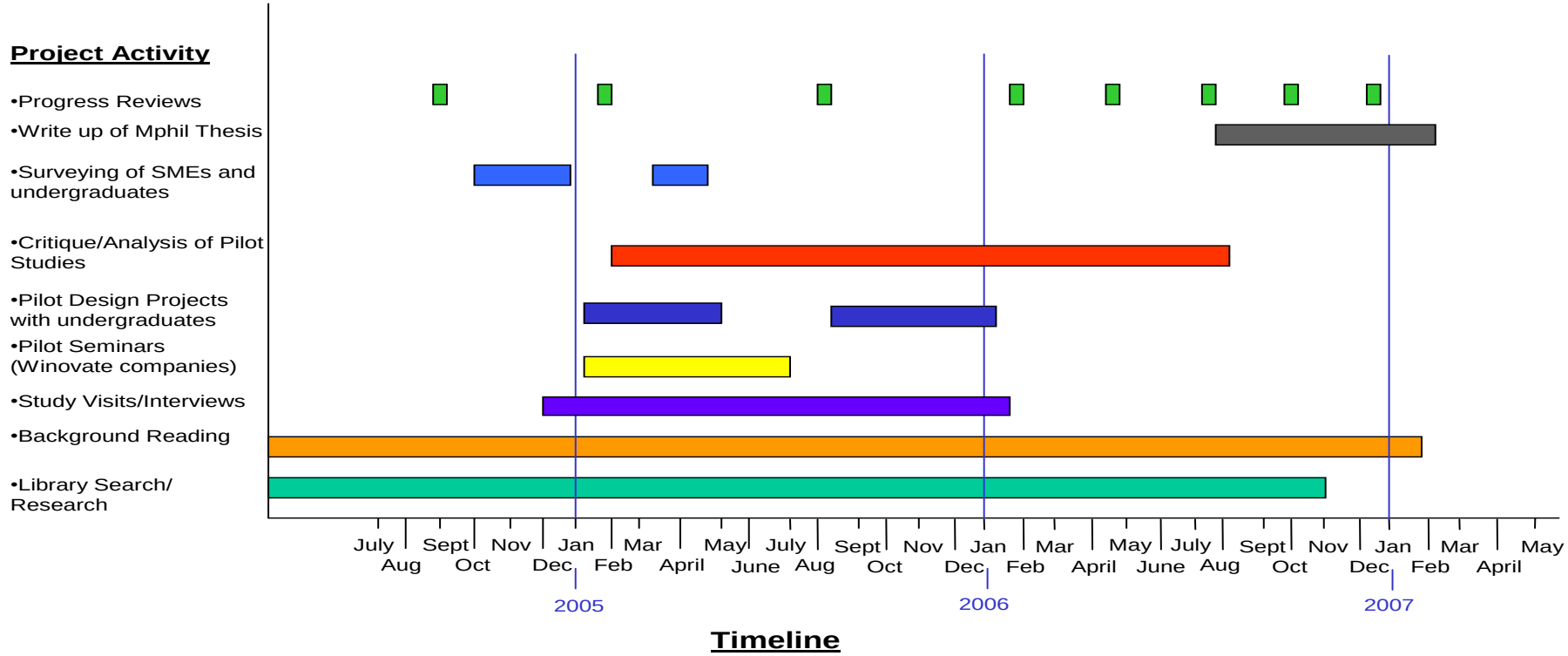
SDI helped to give me the capacity to address and implement sustainable design within our practice - Norman Stevenson (Senior Industrial Designer with Design Partners)

I would say that sustainability is the way of all future living and that it is really important that we get involved now and at all levels. The SDI course is a fantastic course to get you thinking of moving forwards - Fiona Lynch (Graphic Designer with Irish Life)

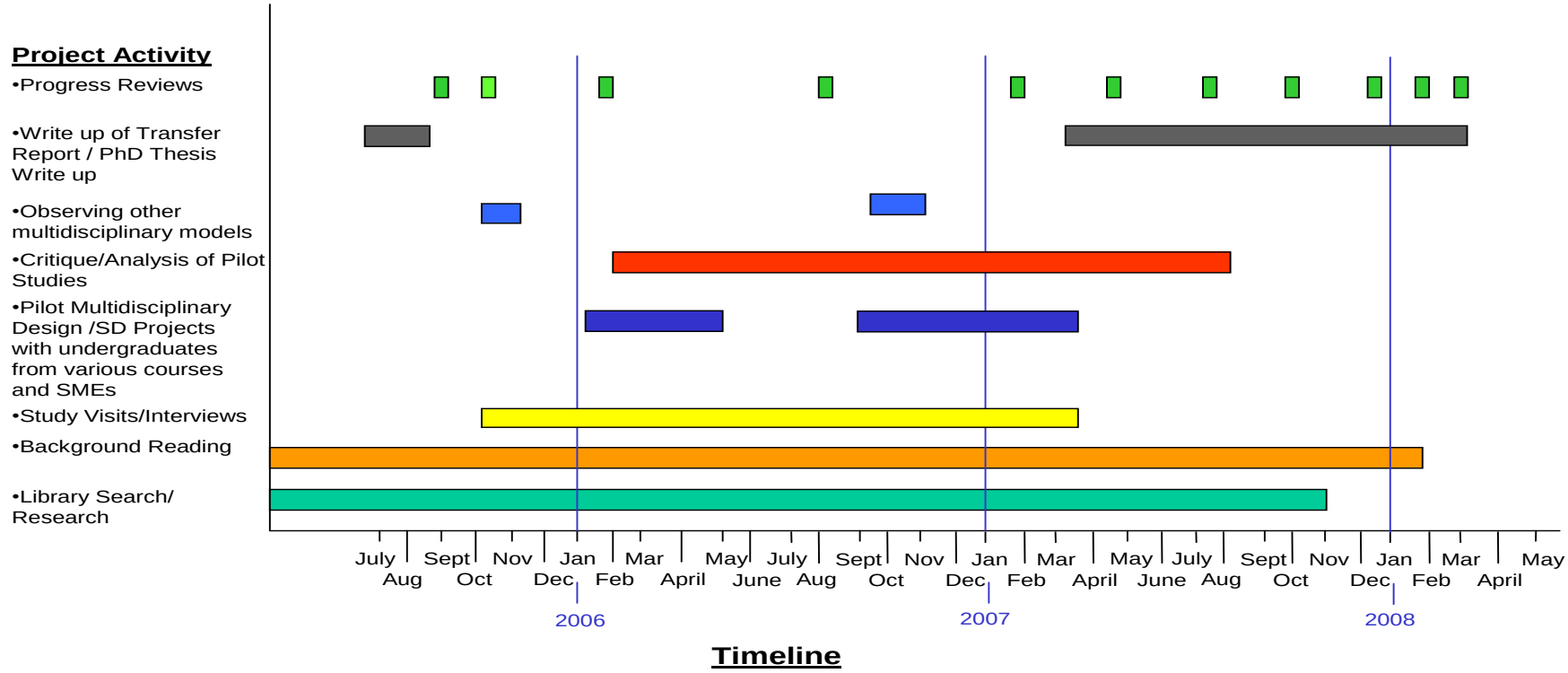
The SDI course gave me the time, structure and learning environment to reach a far greater strategic and tactical understanding of the issues, challenges and opportunities to respond to global climate and sustainability - Paul O'Connor (Architect)

Appendix E. Timelines of MPhil and PhD

Proposed Timeline for MPhil Research



Proposed Timeline for continuation to PhD Research



Appendix F. Briefs from Undergraduate Projects

Institute of Technology Carlow
National Diploma in Industrial Design 2005

Project Brief

Subject: Product Design (Year 1)

Title: Sustainable Packaging Design **Date:** 05-04-05

Objectives:

- To learn how to apply basic Life Cycle Analysis techniques to product designs
- To consider the environmental impacts of design decisions on the overall life of a product

Brief:

Sustainable design is a complex amalgamation of clever and creative design application, material choices, and a clear understanding of the systems and environments that the products will work in. To explore some of the concepts behind sustainable product design it is important to have a clear overview of all these factors. Often industrial design deals only with the aesthetic and user driven elements of such products without consideration for their overall environmental impact.

Your brief is to design and supply sufficient containers for 1,000 litres of sauce to the Safeways sauce factory in Leeds in the UK. You are required to produce two concepts for consideration so as they can be compared for the purposes of their environmental impact. Assuming that you are manufacturing the containers in Carlow, Ireland you will need to consider transportation issues in your design.

While it is possible to optimise the design of the containers for transport and supply only to the sauce factory you should also consider the final use of the product from a consumer's point of view.

You will be using the SPD(Bournemouth) website that we worked on in ESMandP earlier in the year to assist you in the more complex LCA (Life cycle analysis) parts of the design. Specifically if you log on to http://spd.bournemouth.ac.uk/html/introduction_to_your_life_cycl.html You will access this project. The site will guide you through the use of the Eco-packager programme. It is important that you save your work on the Eco-packager programme to your DSN drives and print off your results for presentation. Please ensure you follow all 9 of the steps in the Task completing the quiz and feedback questionnaire.

Deliverables:

STAGE 1: Thursday 9.00am Verbal/Visual presentation of 2 concepts (Sketch renderings)

STAGE 2: Thursday 3.00 outline on how to use ECO Packager, In studio

STAGE 3: Tuesday 12th 10.00am Final presentation of design, (See point 8 of task list) to be verbally presented with the aid of visuals.

Assessment Criteria:

Clear rationalisation of all stages of the design will be essential with justification for materials choice, transport choices and packaging details.

Institute of Technology Carlow

Bachelor of Arts – Industrial Design 2006-'07
BBS- Marketing 2006-'07

IDP1 - CASE STUDY/MDP PROJECT BRIEF

Monday 18th September 2006

RESEARCH OBJECTIVES:

To examine the existing manufacturing company, retail environment, production item issued and investigate using the following areas as a starting point:

Initial Phase: Environment Assessment:

- Corporate identity and branding, principle activities/product offering and market share,
- Target market/user identification, product/market placement, price point, competition (direct and indirect), distribution channels etc.
- Regulatory environment.

Secondary Phase: Strength/Weakness (S.W.) - Product Assessment:

- Packaging, product/user information (supplied), ancillary and online customer support,
- Product presence, aesthetic/styling,
- Product, features, functions, performance, ergonomics,
- Manufacturing, material, finishing, assembly inventory,
- Life-cycle assessment.

DESIGN OBJECTIVES:

There are 2 aspects to this Case Study design brief:

1. Repositioning of product and/or presentation, ***(note: This is NOT a grass and root redesign).***
2. Decommission disassembly in manufacture analysis and recycle/reuse audit.

Note: The purpose of the Case Study Project is to refresh skills in

researching (information gathering), data organisation, analysis and presentation,

in 2D/3D sketching and design skills

and in reporting, writing and communication skills etc.

Phase 1: Submission Element - Environment Assessment Report Wed 20th Sept. @ 3:00

- 1-3 page report/statement of environment, as outlined above *(staple-do not bind)*
- Introduction to **The Product** and brief assessment presentation,
- Analysis of overall '*Product Communication'* to the consumer (as they'd find it in store).
- Initial, impressions of product personality, features, functions, usefulness etc.
- Oral statement of direct/indirect product and corporate/product competition, climate, placement, purchase motivation and statement/assessment of packaging, pricing, etc.

Phase 2: Workshop: Product Dissasembly and DFMAD Thurs 21st Sept. @10.00am

- In studio workshop, products, packaging, rulers etc required

Cont.

Joint Marketing/Design Phases

Phase 3: Assessment Element - Style Board (Crit Presentation)

Suported by research , Focus Groups ,

Scenario: The manufacturer is losing market share, is unwilling to re-invest heavily in this category but does urgently need to address increased regulatory constraints under the WEEE directive and European Packaging directives

1. Consider and generate a design and/or product presentation **modification** strategy.
   You may make proposals on in terms of one of the following:
   - Sustainable Packaging update and product update (i.e. colour, minor detailing, finishing etc.)
   - Market Repositioning, Sustainable packaging, bundling, P.O.S., consumer information etc..

   Consider and generate through a series of sketches leading to three finished proposals. Visualise product proposal and alter product and/or package, P.O.S. etc. use digital photography, photoshop and/or generate a solid works block and/or use foam/card modelling in expressing your ideas.

2. Consider and suggest:
   - Manufacture/material/assembly modifications which may improve efficiency, AND
   - Approach to product decommission, dis-assembly, recycle, reuse etc. which address EU Environmental Directives
   - A suitable Marketing Strategy to capitalise on the new sustainability in the product and packaging

Phase 4: Final Presentation Submission: Final Presentation 2nd Oct. (T.B.A.)

- Prepare a 3-5 minute presentation in Power Point outlining your research and design update proposal, new product brief and/or operational parameter to be in a format suitable to be e-mailed, address T.B.A.). The visual brief is **"Crisp and Clear"**

*Note: Details and any timing of submissions and assessments will be updated on **Blackboard**.*