19th DMI: Academic Design Management Conference
Design Management in an Era of Disruption
London, 2–4 September 2014

An investigation into design thinking behaviours in early stage radical innovation

Martin P. Ryan[a], Frank Devitt[b]

[a] National University of Ireland, Maynooth 'a'; [b] National University of Ireland, Maynooth 'b'

The early stage of radical innovation is characterised by uncertainty, data overload and often high rates of change. Schumpeter's 'creative destruction' view of innovation is now exacerbated by 'hypercompetition' (D'Aveni, 1999), a theory that describers the increasing rate and intensity of change in modern markets. In the design and strategy literature, design thinking is often positioned as an appropriate mediator of radical innovation in these circumstances, by facilitating interpretation of market uncertainties and moderating organisational behaviours.

At its inception radical innovation is determined largely by the cognitive behaviour of the actors involved, often semi-consciously. In this study we set out to distinguish design thinking from analytical thinking and investigate the suitability of both for the effective early stage formation of radical innovation concepts. Additionally, whereas design thinking literature mostly investigates and reports on the benefits of its application, we seek to understand where design thinking's limitations lie and where it may be better replaced by other forms of cognition. This paper reports at an interim stage of a continuing study. It provides a comprehensive review of relevant literature and a qualitative exploration of two successful innovating SME firms. A framework is given for a novel experimental protocol that will be used in the next stage of the larger study.

***Keywords**: Design thinking, radical innovation, emergent strategy, cognitive models, strategic decision making*

Introduction

Increasingly, competitive industries seek to target radical innovation as a route to strategic competitive advantage. But high levels of market and technological uncertainty, coupled with organisational complexity and competitive intensity mean the route to success in pursuing this radical agenda is far from clear.

The knowledge base surrounding new product innovation is predominantly concerned with the 'back end' of new product development (NPD). According to Buxton, our knowledge system is out of balance, "…we must adopt an approach that inherently aspires to get the right design as well as get the design right. The former, which is one of the prime objectives of the up-front design phase, is the part that is too often absent in today's practice" (Buxton, 2007 P.78).

Successful radical innovators employ various strategies. Sometimes they identify new uncontested markets (W. C. Kim & Mauborgne, 2004; W. Chan Kim & Renée Mauborgne, 2005); or they change the meaning of existing markets (Verganti, 2009); or, they change the rules of competition to favour them and disadvantage their competitors (D'Aveni, 1999); or, they use combinations of all these and more. In each case they face acute uncertainty, even more so at the very early stages, when identifying market opportunities and proposing radically innovative solutions. It is uncertainty that chiefly characterises the early stages of radical innovation (ESRI) and influences the nature of strategic decision making. Under this uncertainty the traditional and more dominant analytically-based models are less useful (Marren, 2010; Mintzberg, 1994). Further, it is not always a matter of choice whether to pursue radical game changing initiatives; instead in a growing number of markets it is a reality of survival (D'Aveni, 1999). It is with this in mind that the literature is calling for new research from which models and tools can be developed, and to help counteract our overreliance on analytical thinking and frameworks (W. Chan Kim & Renée Mauborgne, 2005). An increasing number of authors now propose that design and design thinking are particularly suited to bring value and tractability to this dilemma (Kotler & Rath, 1984; Martin, 2009).

ESRI accounts for up to 50% of the overall innovation development time (Smith & Reinertsen, 1991). Proficiency in ESRI is a key determinant in the success of firms involved in radical innovation and is the stage at which many of the final characteristics of the innovation are determined (Khurana & Rosenthal, 1998). It is the major determinant of speed to market and therefore a prime source of early mover advantage over rival firms

(Langerak and Hultink cited in Brentani & Reid, 2012, P.73). Yet, it is poorly understood and there is a dearth of strategic tools to effectively manage the "fuzzy front end" activities.

This paper provides an interim report on a study of the extent and nature of DT behaviours in radical early stage innovation decision making.

In the following sections we describe ESRI and its theoretical base, as it has been thus far developed. We also identify the micro-behaviours of design thinking and its theoretical foundations. We set out our research strategy and we draw on analogy with entrepreneurship research to develop a research instrument. We categorise three cognitive styles of strategic decision making: Analytical reasoning (ANA), DT non-analytical reasoning (DNA), and other non-analytical reasoning behaviours (ONA). Each is described and defined for data-coding purposes.

Finally, we validate the research instrument framework and sequence against empirical findings from interviews with a preliminary sample of expert innovating organisations; suggest improvements and set clear guidelines with which to progress our empirical investigation into ESRI.

Research objectives and methodology

In this paper, we draw on parallels with Sarasvathy's successful study of the early stages of business formation by analysis of the cognitive styles of expert entrepreneurs (D. Sarasvathy, 1997; D. Sarasvathy, Simon, & Lave, 1998; Saras D. Sarasvathy, 2001; Saras D Sarasvathy, 2009; Saras D Sarasvathy, Dew, Read, & Wiltbank, 2001) and we propose a derivative methodology to help research and better understand the front end activities of ESRI. Using a novel research methodology, Sarasvathy empirically characterised key elements of entrepreneurial expertise in contrast to traditional business planning approaches (Saras D Sarasvathy, et al., 2001). In doing so, she expanded understanding of the 'pre-firm' and its associated problem space (D. Sarasvathy, 1997).

The overall study's objectives are to establish the nature of design thinking behaviours, the extent of their use and the benefits that accrue from these types of behaviours. In addition, we wish to determine the circumstances in which they are most beneficially applied and, of equal importance, when they are less suited than traditional, more analytical approaches. We hypothesise that many ESRI activities are essentially design thinking in nature, even if not explicitly identified as such. Due to limited literature and understanding of ESRI this qualitative study draws from a wide theory base and is exploratory in nature.

The overall study encompasses three phases.

PHASE 1: Retrace existing innovation development patterns and establish key elements and process sequence.

PHASE 2: Map expert innovation process by concurrent cognitive experiment and establish the sequence of micro behaviours (cognitive approach) and their nature. Phase 2 will draw on phase 1 findings to validate an experimental research instrument.

PHASE 3: Confirm the extent of the role of DT in early stage radical innovation.

This paper reports on phase 1 completion. Here, we prepare guidelines towards a research instrument for cognitive experiment. Through phase 1 we have conducted semi-structured interviews creating case studies of 6 innovation events (3 separate innovation events in 2 different firms). Interviews were conducted using grounded theory principles (Moghaddam, 2006). Interviewees self nominated based on their involvement and comprehensive knowledge of the innovation event in their organisations. Three separate individuals were interviewed for each innovation to ensure complete and accurate process mapping. Any inconsistencies were later revisited and corrected.

In practice, radical innovation is a long process. Practical limitations do not afford a longitudinal study so our experimental protocol uses a research instrument that frames a hypothetical, though realistic and empirically validated, scenario set and problem space. The instrument will present ESRI scenarios with decision-making tasks designed to elicit evidence of cognitive styles and behaviours. By 'think aloud' verbal reports we propose to capture cognitive responses of subjects. In this paper we offer taxonomy of cognitive styles for coding. Two forms of analysis will follow. Quantitative analysis will determine the proportional contribution of each cognitive style to ESRI, qualitative analysis will inductively extract principles for applying DT to future ESRI. This paper establishes rules by which to develop the experimental protocol problem set including its problem space, sequence and actor characterisation. From it industry specific experiments may be developed by adaptation of a previously reported event or creation of a brand new event, convincingly real.

Innovation typologies: Radical v. Incremental

Radical innovation is a complex concept, often involving unstructured processes, surprising events, and disruptive outcomes. Innovation derives from the Latin word 'innovare' which is to renew or alter and 'novus', meaning new, fresh or young. For the average person in the street: Innovation is 'doing something new'. For the scientist or engineer: Innovation is 'inventing or discovering something new'. For the designer, business person or economist: Innovation is 'doing something new that adds economic value through user adoption.

Radical is drawn from the Latin word 'radicalis', meaning of-root or fundamental. Prefixed to innovation it implies a fundamental or root change. In context of business innovation it asserts a degree of change affected at systems level. In sum, radical innovation is a 'change of frame', "doing what we did not do before" where as incremental innovation 'improves within a given frame of solutions' or "doing what we already do" (Norman & Verganti, 2013, P.82). Therefore radical prefixed to innovation demands a threshold of change beyond incremental.

Norman and Verganti offer a 'hill climbing' analogy to distinguish between incremental and radical innovation (see
Figure 1);

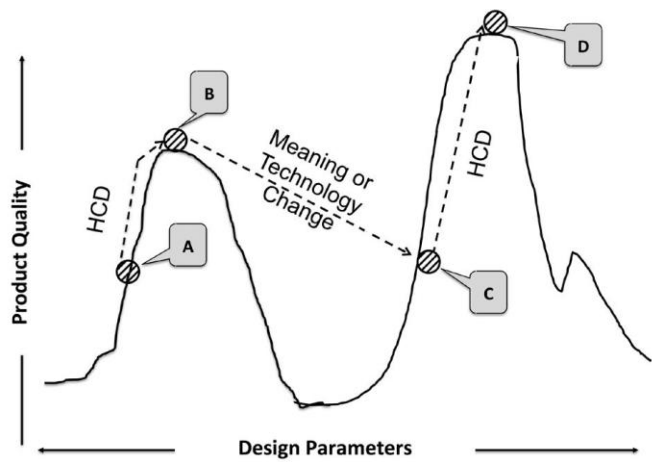

Figure 1: The hill-climbing paradigm applied to incremental and radical innovation (Norman & Verganti, 2013 ,P.79)

> *[Incremental Innovation:] A given product might start off at "A." Through Human-Centred Design and Design Research (HCD & DR), the product undergoes a series of incremental innovations, eventually bringing it to its maximum quality for this part of the design space, point "B."*
>
> *[Radical Innovation:] To move to a different hill, one with a higher potential, requires radical innovation, and this comes about through either technology or meaning change, leading to point "C" on a larger hill. Note that the initial outcome is often inferior to that previously reached ("B"), and so HCD and DR are required to make the necessary incremental innovations to reach maximum potential. To make matters more complex, when the product is at point "C," there is no way of knowing if indeed there is a superior level ("D") or if this is an inferior spot in the design space. (2013 ,P.79)*

Radical innovation can be further categorised into different dimensions. We draw on Bessant and Tidd's (2007) 4Ps of innovation space. Here they capture the two degrees of innovation, radical and incremental, along four dimensions; **Product innovation** reflects changes in products and services, **Process innovation** reflects changes in the how things are created or delivered, **Position innovation** changes in the context in which things are introduced, and **Paradigm innovation** describes changes in an underling organisational model. The 4Ps model offers a common platform to measure and compare disparate innovation types and specify their place along the incremental-radical continuum.

We define radical innovation as *a new product, process, position or paradigm that significantly alters the natural progression of a market or industry, to meet one or more of the following conditions of degree;*

> *A. Reach non-customers of an existing market space. Customers that otherwise would not naturally enter the market. (For further definitions see Kim and Mauborgne's three tiers of non-customer (2005))*
>
> *and/or*
>
> *B. Significantly undermine incumbents by changing the rules under which an existing market operates, necessarily with or without performance benefit to the customer. (For further reading see hypercompetition theory (D'Aveni, 1999))*

The Early Stage of Radical Innovation

Here we introduce extant literature on the topics relevant to early stage of radical innovation bounds, its process and sequence, and its decision making problem space.

Background

ESRI literature makes up a small part of innovation literature. The majority of the literature relates to later project execution and management issues with a relatively small portion addressing front end activities. Of those addressing front end activities, they typically expand on linear phase models focusing on 'pre-project activities'(Smith & Reinertsen, 1991), phase 0 and pre-phase 0 (Khurana & Rosenthal, 1998), stage 0 (Cooper cited in J. Kim & Wilemon, 2002), fuzzy-front-end (FFE) (J. Kim & Wilemon, 2002; Smith & Reinertsen, 1991), or front end innovation (FEI).

ESRI activities address all activities prior to NPD, where a project achieves 'new product development' status. Khurana and Rosenethal (1998) describe it as the episode before go/no-go decision when a business unit commits to funding or launches a NPD project. They expand on linear phase models of NPD processes so to recognise two additional phases, 'Pre-phase 0' and 'Phase 0'. Pre-phase 0 is an ongoing, ill-defined activity, whereas Phase 0 concerns the preparation of a NPD project proposal for formal decision gate approval. Similarly, Kim and Wilemon adopt the term 'fuzzy frond-end' and define it as "the period from when an opportunity is first considered and when an idea is judged ready for development." (2002, P.269). In this paper we draw significant contribution from De Brentani. She draws similar bounds but allows for a more open-ended inception point, describing "…the time and activity prior to an organization's first screen of a new product idea."(2012, P.70) Other important literatures and concepts include Cooper's 'Stage 0', a poorly understood set of activities preceding his popular stage gate process, and Reinersten's 'fuzzy front-end' portrayal of pre-project activities undertaken. While there is some consensus to the concluding point of ESRI, its start is much more unclear and currently without consensus.

It is not unusual for very early activities to be acknowledged by contributors and yet in the same writing excluded from the investigation (Khurana & Rosenthal, 1998). This is normally an outcome of practical research constraint. An exception to this is offered by Reid and De Brentani 'fuzzy front end model of discontinuous innovation' (Brentani & Reid, 2012; Reid & De Brentani, 2004). Here they prepare an ambitious model for study into the frontiers of ESRI. They describe a start process which is bottom-up initiated by semi-autonomous individuals who traverse organisation boundaries in search of new knowledge. They bring together a number of complex issues including radical innovation, early stage processes and bounds, and key individual roles. To inform the research instrument, we draw on wider contributions from literature to strengthen weak points in De Brentani and Reid's model, clarifying the radical innovation process and problem space.

The ESRI process

Reid and De Brentani (2004) and later De Brentani and Reid (2012) offer the most complete early stage radical innovation model. They distinguish a radical process from an incremental process by its orientation and sequence. Semi-autonomous activities by individuals initiate new information flow from the environment into the organisation.

> *For incremental new products, structured problems or opportunities typically are laid out at the organizational level and are directed to individuals for information gathering. In the case of discontinuous innovations, however, we propose that the process works in the opposite direction—that is, that the timing and likelihood of organizational-level involvement is more likely to be at the discretion of individuals. (Reid & De Brentani, p. 140)*

In total, three decision-making interfaces exist and effect information flow through the ESRI process. A boundary interface (between individual and environment), a gatekeeping interface (between individual and organisation) and a project Interface (between organisation and specific project team). Transition between interfaces is controlled by a key individual in each case. Only at the third and final interface, the project interface does the route of control reverse. On achieving NPD status direction is centralised by appointment of project level decision makers.

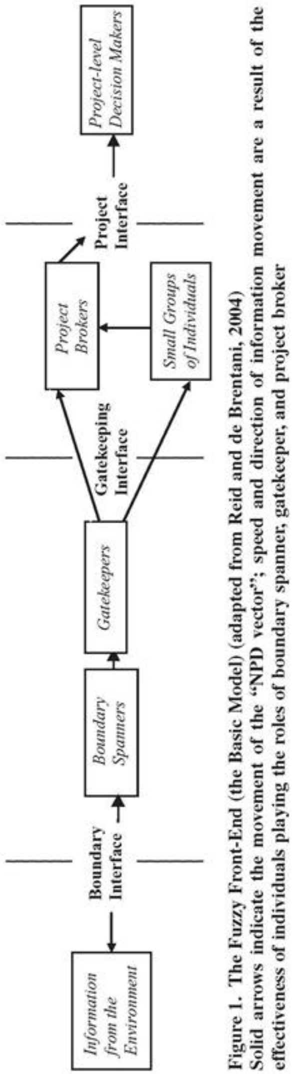

Figure 2: (Reid & De Brentani, 2004)

Fundamentally ESRI is an information processing activity whereby new information is translated into innovation concepts and strategies (De Brentani and Reid, 2012, P.71). Accordingly, quality and speed of information flow are key determinants of process effectiveness. Quality is determined by communication effectiveness. The ability to encode information for transport, transport and decode after transport determines concept appropriateness and integrity. Speed determines the efficiency by which processing is completed and early-mover advantage. Effectiveness of both variables is determined in different ways at each interface. We extract guidelines for the research instrument by exploring each phase.

Boundary phase variables

The first of three phases is the point at which new information enters the organisation. According to De Brentani and Reid the process effectiveness at the boundary phase is dependent on three key variables; (1) Innovation attributes, (2) boundary spanner positioning both inside and outside the organisation and (3) ability to assimilate new information patterns.

Innovation attributes pertain to levels of discontinuity between new information and existing organisational activity. That is, the greater the discontinuity, the greater the challenge in recognising its relevance in the first place. Discontinuous pattern recognition requires multiple waves of opportunity recognition prior to any action (cited in Brentani & Reid, 2012, p. 75). Secondly, effective boundary spanner positioning requires a broad and diverse networks base. Positioning beyond well established market linkages is an indicator of breadth. Thirdly, the individual's ability to assimilate relevant information requires perception or classification of new information patterns. We draw on the concept of 'absorptive capacity'. It states; "the ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge" (Cohen & Levinthal, 1990, P.128). Accordingly, learning is more difficult in novel domains as existing concepts are less richly connected. A diverse knowledge is advantageous where there is uncertainty in order to increase the likelihood of novel connection between patterns. A narrow skill focus, or capability bias, restricts exploration and breadth of linkages (March, 1991; Zhou & Wu, 2010).

For our purposes variables 1 and 3 overlap, and so combine to form a single implication for the research instrument. In sum, there are 2 implications for the research instrument;

Firstly an existing knowledge set that is broad should positively promote *radical connections. A measurement scale will have two poles – narrow knowledge base v. broad knowledge base.*

Secondly network positioning should be broad and diverse. A measurement scale will have two poles - redundant (only established market networks) v non-redundant (broad and diverse networks).

Gatekeeper phase variables

The second of three phases sees the introduction of an organisation layer in decision making. At the gatekeeper phase, information is processed in terms of relevance to the organisation and includes three relevant variables: (1) perceived attributes of evolving innovation concepts, (2) established internal relationships and structures, and (3) ability to communicate new information. Two further variables include individual motivation and extraversion; both influence speed of flow but are beyond the scope of this study.

By the first variable, gate keepers perceive new information through their individual value lens and organizational strategic values. To better understand the nature of the process we draw on two related concepts; firstly, Khurana's and Rosenthal's 'holistic front end'; "This means understanding the link between business strategy and NPD, simultaneously considering the portfolio of product development efforts and objective assessment of the particular NPD opportunities" (1998, P.59). Secondly, Hambrick and Mason's decision making model. In particular 2 constructs; the organisations 'limited field of vision' and individuals 'cognitive base and values'. Limited filed of vision describes strategic areas to which attention is directed and bounded by existing organisation activity (1984, P.195). Cognitive base and values are individual 'givens' or assumptions. Together they situate or frame patterns for relevance to company and individual. In terms of this research the 'field of vision' guides initial search activity at the boundary phase and their cognitive base and values relate to an individuals cognitive styles, or information processing behaviours (for example analytical v non-analytical discussed later).

By the second variable, the nature and strength of internal relationships determine flow effectiveness. In practical terms, this implies that an individual acquainted with a diverse set of individuals will be more likely to receive broad disciplinary feedback, which is known to promote innovation. Wider literature suggests innovation novelty and relevance suffers where such groups are myopic or dominated by a single capability (Zhou & Wu, 2010). In light of this, human bias accentuates this negative as individuals are more likely to share embryonic concepts within their immediate groups (Brentani & Reid, 2012). A further consequence of divisional boundaries and the grouping of disciplines, normal to organisations, i.e. engineering department, marketing department, finance department etc. Organisation structures may indeed be a prolific inhibitor of radical innovation with the following exceptions; where individuals are inclined to cross divisional boundaries (McDermott & O'Connor, 1999); where process promotes this to happen (Khurana & Rosenthal, 1998); or where breadth of knowledge is within the individual (Khurana & Rosenthal, 1998). In each case flow and quality of innovation concepts will improve.

By the third variable, flow and quality of information is affected by the gatekeeper's aptitude for communication. The provision of good context, linking technical and market applications speeds up the process of information sharing (Brentani & Reid, 2012).

In sum, there are three implications for the research instrument;

> *Firstly new information patterns are filtered through 3 legacy organisation elements; the overarching or gestalt strategy (Mintzberg, 1978), the portfolio of existing products, and the individual cognitive style. In order to isolate the individual's cognitive style the research instrument must set out of the other two variables, the gestalt strategy and existing product portfolio. Appropriate measurement scale – Analytical v. non-analytical of which design thinking is one form.*
>
> *Secondly, a gatekeeper who seeks breadth of experience in sharing and validating opportunities is shown to enable innovation, whereas normal organisational divisions impede gatekeeping but are commonplace. The research instrument must determine normal organisation conditions in order to assess gatekeeper practices. Appropriate measurement scale - Narrow disciplinary focus v. broad disciplinary focus. As stated by Khuarna and Rosenthal, breadth may be within the individual or fostered by the process (1998). Therefore special consideration is necessary for individuals with breadth of knowledge.*
>
> *Thirdly, greater visibility between market and technology linkages facilitates radical innovation. The research instrument must set out conditions to evaluate the nature of communication mechanisms and their ability to communicate context across different innovation dimensions (4Ps). Appropriate measurement scale - Analytical v DT or other non-analytical.*

Project phase variables

The third and final phase is the point at which the project is officially accepted or rejected by central management. According to De Brentani and Reid process effectiveness at the project phase is dependent on a 'project broker', a position normally fulfilled by a senior manager. Here the broker prepares and introduces the idea for its formal screening, setting out its connection to current strategic context. Three key variables include; (1) existing organisation competencies, (2) new project decision criteria, and (3) speed through decision gate.

By the first variable, radical projects may have competence destroying implications for the organisation and therefore be rejected.

By the second variable, an organisation that presents rigid decision structures may slow or even kill a radical innovation, particularly where decision criteria are onerous. Good Broker navigation will speed up this process and flexible gates are recommended to allow brokers to champion and adapt decision criteria to something more relevant.

By the third variable, early broker involvement ensures faster evolution of any innovation concept. Seniority of project broker brings with it experience and understanding in negotiating decision criteria particular to that organisation.

In sum, there are two implications for the research instrument;

> *Firstly, radical innovation is often competence destroying. This combined with formal decision criteria impedes fast decisions. The role of the Project broker is to prepare NPD proposal for formal decision gate and overcome barriers fast. In doing so they must satisfy a number of conditions including meshing new opportunities within the current strategic web and work round ill-suited formal decision criteria. The research instrument must set out realistic organisation criteria for project approval and provide a radical innovation concept. By this we may isolate broker ingenuity and make visible their cognitive mechanisms for measurement. Here, we seek to record and measure both the communication tools adopted and broker emphasis in terms of targeted validation criteria and negotiation behaviours, overcoming problematic criteria. Appropriate measurement scale – analytic v. DT or other non-analytic approach.*
>
> *Secondly, delayed broker involvement is likely to delay project approval. The research instrument should determine at what point project broker (senior manager) involvement is sought. Appropriate measurement scale - initial instances of gatekeeping v. just prior to project decision gate*

The initial problem space

A key determinant of process initiation is the problem space in which it exists. Interestingly Sarasvathy deals with strategic choice under uncertainty. While this methodology follows Sarasvathy's there are some notable differences. In particular, entrepreneurship deals with a pre-firm problem space, whereas we deal with a pre-innovation problem space. An entrepreneur does not inherit the benefits or burdens from firm history and as a result easier for the entrepreneur to impose personal values, goals & motivations in decision-making (D. Sarasvathy, 1997), whereas a boundary spanning individual acts within an organisation and is therefore bound by an extra organisational layer of influence. For purpose of framing this discussion we expand on the three elements of the pre-firm problem space; Knightian uncertainty, goal ambiguity, environmental isotropy (Saras D Sarasvathy, 2009) and include legacy organisation factors.

Knightian uncertainty distinguishes between predictable futures and unpredictable futures. Faced with Knightian uncertainty it is impossible to calculate probabilities for future consequences. Two seminal theories characterise the unpredictable problem space; 'artificial science' (Simon, 1985) and derivative concept of 'wicked problems' (Rittel, 1973).

According to Simon artificial problems are solved by the logic of thought that is flexible to ever changing inputs, constraints and variables, whereas natural sciences asks for purely empirical data and facts and ordinary declarative reasoning to explain precise relationships (Simon, 1985, P.150). Artificial problems are creations of human intention and emotion bounded by natural laws;

> *The world we live in is much more a man-made, or artificial, world than it is a natural world. Almost every element in our environment shows evidence of mans artifice. The temperature in which we spend most of our hours is kept at artificially at 20 degrees Celsius; the humidity is added or taken form the air we breadth; and the impurities we inhale are largely produced (and filtered) by man (cited in Saras D Sarasvathy, 2009, P.152).*

'Wicked problems' exist within the artificial sciences and describe a problematic juncture where goal formulation, problem definition and equity issues meet (Rittel, 1973). Strategic choice is implicated as follows;

> *In a world of Newtonian order, where there is a clear relationship between cause and effect, companies can judge what strategies they*

want to pursue. In a wicked world of complex and shadowy possibilities, enterprises don't know if their strategies are appropriate or what those strategies' consequences might be. They should therefore abandon the convention of thinking through all their options before choosing a single one, and experiment with a number of strategies that are feasible even if they are unsure of the implications. (Camillus, 2008, P.104)

Secondly, an implication of an artificial problem space is 'goal ambiguity' and 'environmental isotropy'. Upfront goals require conditions for prediction, in its absence goals are neither given nor well ordered. Here non-predictive control replaces predictive control. In an infinite range of possibilities it is not clear what elements of the environment to pay attention to and what to ignore. Further to this, wicked problems are never truly solved but exist without a stopping rule.

Most radical innovations are synthetic, man made creations, bounded by natural science but guided by human intention. At its initiation a radical innovation problem space exists along degrees of human intention. At its lowest, human intention is inconsequential and innovation arises from a technology breakthrough and carries no socio-cultural change. At its highest, human intention is significant, innovation is meaning driven and a new socio-cultural model results.

In sum, an implication for the research instrument;

Starting out, radical innovation possibilities are infinite, goal constraints are incomplete and environment signals are neither prioritised nor well ordered. Future conditions are not predictable. Two control factors simultaneously processed by individuals determine early goals; firstly organisational layer control and secondly individual cognitive style control. The research instrument must provide the environmental stimuli, characteristically ambiguous and isotropic, and organisational layer control conditions in order to isolate and observe the individual cognitive control styles. Appropriate measurement scale - Analytical v DT or other non-analytical.

Cognitive styles in decision making: Analytical Thinking v. Non-analytical thinking

Here we introduce literature on topics relevant to the actors in the process. We delineate a taxonomy of cognitive styles, distinguishing Analytical Thinking from Design Thinking.

Suitability of cognitive style is dependent on the nature of the problem space and existing organisation attributes. Analytical reasoning is useful in domains of clarity, where all variables are known to the decision maker and the future is predictable (Saras D Sarasvathy, et al., 2001). “According to the logic, once a problem is comprehensively stated the optimal solution can be rationally derived from the inner structure of the problem” (Lindberg, Gumienny, Jobst, & Meinel, 2010, P.244 drawing on Newel et. al 1967).

Sarasvathy (2009) distinguishes two forms of analytical reasoning, deductive reasoning and Bayesian probability. Deductive reasoning deals with wholly objective issues and exemplifies the natural sciences, whereas Bayesian probability deals with subjective issues by means of rational methods. In this instance problem space uncertainties are transformed into factual statements so that it becomes susceptible to analytical techniques. Notably, both methods have different problem spaces at the start, one is to some degree subjective and while the other is wholly objective, but interestingly both adopt analytical reasoning tools in solving the problem space.

Non-analytical is a catch all term we use to describe all approaches that do not fit analytical reasoning. Like Bayesian probability, non-analytical approaches address subjective issues, but unlike Bayesian probability the problem space is left uncertain while solving and non-analytical means are adopted. Effectuation is at least one known embodiment of this, described by Sarasvathy as the inverse of analytical processes. Others both good and bad include intuition, chaos, chance, magic, etc.

For the purpose of analogy we draw on the introduction of the Nintendo Wii to the game console market to help distinguish between Analytical, Bayesian and Non-analytical (design thinking) cognitive styles in practice.

At its inception the game console market was technology driven, focused on passive immersion in a virtual world (Verganti, 2009). Market share was won and lost by an organisations ability to deliver graphical realism. At this time one might declare the problem space as follows; Nerdy gamers need the latest technology. Moore’s law says every 2 years technology will have 10 times the power currently available. Therefore we know gamers will expect 10 times better games.

We hypothesise 3 different possible responses, analogous to 3 cognitive styles in practice:

> *Analytical – From market truths we can deduce the level of improvement necessary. We can plan in advance the necessary steps for execution.*

Bayesian – Xbox and Playstation have a technology advantage we cannot make up. We know that many people do not consume game consoles but we don't know how many latent customers there are. By conducting surveys and reviewing market analytics we may predict the number and nature of potential customers. Based on this prediction we can define the exact solution.

Design thinking – Xbox and Playstation have a technology advantage we cannot make up. It is reported that consumers cut back on game consumption as they start families. In our broad experience gaming is not very interactive when in the presence of other people and it focuses on a narrow set of technologies. What if we did something for the family? Let's build a quick experimental model to see how they respond and learn from this.

Possibly the key distinguishing element between analytical reasoning and non-analytical reasoning are their lines of inquiry. According to Bamford (2002) analytical process adopt an analysis/synthesis line of inquiry. Non-analytical process adopts a conjecture/analysis line of inquiry. An analysis/syntheses model seeks absolute truth from the start. Conjecture/analysis draws on Popper's pragmatic view of truth as ultimately a matter of professional agreement among scientists and only requires the appearance of truth. Here, relative truth is declared at the end of the process once proven satisfactory in a follow-up analysis. By Popperism, truthfulness and accuracy of a stating hypothesis doesn't matter as it is ultimately unimportant to its resulting acceptance or rejection. In other words, if a guess is made and it is tested and found out to be good, then the outcome is accepted.

In the case of radical innovation this releases future possibilities from the restrictive grip of declarative accuracy. As not all methods of hypothesis construction are rationally definable it affords broader approaches to hypothesis creation. Analytical reasoning is conditioned on declarative statements drawn from historic patterns.

This orientation of inquiry is further lived out in Sarasvathy's distinction of analytical logic as predictive control v. effectual [non-analytical] logic of non-predictive control.

In sum, there are a number of implications for a coding scheme:

Evidence of analytical reasoning:
1) An analysis/synthesis line of inquiry. 2) Subject defers design decisions in search of declarative statements. 3) The design solution is strictly modelled on historic patterns. 4) A prediction control mindset is apparent. 5) Subject

assigns all market influence to external firm factors.

Evidence of non-analytical reasoning:
1) A conjecture/analysis line of inquiry. 2) A non-predictive control mindset is apparent. 3) Subject believes in their ability to influence the market

DT as a form of non-analytical reasoning

Design literature firmly positions design cognitive styles with non-analytical reasoning. Bousbaci (2008) distinguishes design thinking from classical scientific thinking by two dimensions, focus and outlook. He describes scientific thinking as a 'problem focused' approach, characterised by steadfast pursuit of the problem presented. Whereas design is described as a 'solution focused' approach, characterised by problem apathy, pursuing a quality solution to a problem not necessarily the one started with.

Similarly, Schon and Buxton distinguish between 'problem solving' and 'problem setting' (cited in Buxton, 2007, P.384), Buxton aligns analytical traits to problem solving expertise and design thinking traits to problem setting expertise. Schon distinguishes between scientific and design lines of inquiry. Science is convergent and depends on 'agreement about ends'. Design practice is divergent and adopts non-technical process, framing problem situations where 'there is yet no agreement about ends'(1991, P.41). Liedtka (2000) differentiates a design approach from traditional planning approach to strategy as being more widely participative; more dialogue based, issue-driven rather than calendar driven, conflict using rather than conflict-avoiding, where they all aim for invention and learning in place of control. According to Martin (2009) a reliability focus is consistent with analytical reasoning and perpetuating the past. A validity focus is consistent with exploration, innovation and design thinking.

Van Aken (2004) distinguishes between 'explanatory science' and 'design science' along 3 dimensions, reputation systems, control rules and outlook. Explanatory science is characterised by an academic reputation system that rewards rigour whereas design science is characterised by a professional reputation system that rewards relevance. Explanatory science follows a quantitative recipe using algorithmic rules and evidence may be left out after it has been assessed, whereas design science follows heuristic rules based on variants of a design exemplar and evidence must remain part of the results. Explanatory science is description driven, seeks an understanding of phenomenon, whereas design science is prescription driven, designing of solutions in context.

In summary, there is a clear dichotomy between design thinking and analytical thinking. It needs to be noted however, we are not saying design professionals don't practice analytical thinking, or scientists don't practice design thinking. Rather any one individual will use different types of reasoning faced by different circumstances. We have simply isolated cognitive styles as the unit of analysis rather than the individual.

In conclusion, design thinking is a form of non-analytical reasoning inverse to analytical thinking. It constitutes a distinct mode of reasoning based on an entirely separate logic.

We summarise the key differences in the Table 1 below.

Table 1 Analytical thinking v. Design thinking

	Analytical thinking	**Design thinking**
Line of inquiry	Problem focus	Problem unbounded
	Problem solving	Problem setting
	Convergent thinking	Divergent thinking
Reputation system	Reliability	Validity
	Rigour	Relevance
Decision rules	Algorithmic rules	Heuristic rules

Empirical validation of the research instrument framework

For purpose of validating our theoretical assumptions of radical innovation process model and its environmental characteristics, we draw on a set of empirical interviews conducted in phase 1 of the larger study. Interviews focused on 3 innovation events within the recent history of 2 organisations which are both experienced in radical innovation, and award winning industry leaders.

We offer a summary of one innovation event captured in phase 1 and follow with a discussion on its similarities and contradictions with our theoretical model.

This innovation event pertains to a device for the accurate detection of heat cycles in dairy cows: The total innovation episode from first cognitive trigger to product launch lasted for a total duration of 5 years, from 2003 through 2008. We have identified the ESRI phase to have concluded in 2005. There after the project had NPD status. We locate the innovation event and its development sequence onto our theoretical model.

Starting environmental conditions

Organisational layer - In 2003 the organisation was already a well established and a successful player in the dairy equipment market, in particular focused on the manufacture and supply of milking parlours to both Irish and international markets. It had good mechanical engineering resources but limited software capability.

Market status – At this time an issue for detecting fertility in cows for dairy farmers existed and was known by the wider industry. Most farmers practiced fertility detection in cows by simple observation. Some basic technologies existed with limited accuracy. Technologies were based on step counting which required twice daily monitoring in order to check device display, normally practiced at milking time. Its detection method monitored a single symptom whereas human observation afforded multi-symptom checks. Technology to replicate human detection methods was not yet implemented.

Boundary spanning events:

There was clear evidence that this innovation process commenced from boundary spanner activity. At the start of the process the boundary spanner was cognisant of financial losses to the farmer experiencing poor fertility detection. He was particularly sensitive to the accuracy limitations of the current step counter technology on grass fed farms as against grain fed farms. In Ireland, most farms practice grass feeding and this magnified any deficiencies in step counters. The boundary spanner was sensitive to this as Ireland was the organisations home market. Here, the grass fed cow moves around more and is inconsistent in its daily movement, whereas the grain fed cow is less active because of corralling. A heat cycle brings about significant increase in general movement, this change is more sharply contrasted in the corralled cow and thus suited to step counting technologies.

A point of breakthrough sparking the innovation cycle started when the passive awareness of the problem was stimulated by the new awareness of a technology breakthrough. The boundary spanner was active in reading technology journals and as a result triggered the first significant innovation event. An episode of pattern matching connected a technology breakthrough to the market need.

Gate keeping events:

Next the boundary spanner turned gatekeeper, aware of the opportunity he started to informally discuss it with colleagues. The key breakthrough occurred on a flight to North America with an international sales manager. During the flight the opportunity was informally discussed and its market potential was affirmed by the second party. This moved the idea forward to a number of exploratory exercises coordinated by the gatekeeper.

Project status approval:

Over several informal meetings a plan of action was put into operation. A number of tasks were identified following gate keeping activities. Software and mechanical resources were engaged to develop a wearable housing to allow technology testing. Video analysis was conducted and correlated against digital readings. Algorithms were created to trace a number of symptoms and expose heat cycles. Following these steps the first complete offering was available for reliability testing in the field.

At a second, later stage additional new resources were added indicating a further commitment to project, including the hiring of a dedicated sales person at which point the product was launched to market.

Confirming radical innovation status:

This product matured into a radical innovation satisfying 2 conditions; reaching non-customers of existing technologies, and affecting new competition rules for the industry. After two years on the market, unexpected demand came from animal breeding companies in place of farmers. The focus of sales channels shifted from milking equipment dealerships towards artificial insemination companies and by good performance they grew and expanded the market for fertility detection devices. Farming is now undergoing a change in meaning from manual farming methods to smart farming significantly led by technology improvements in wearable sensors.

Implications for research instrument

Our findings from preliminary interviews support the first two phases of process model, the boundary and gatekeeper stages. However, at the project interface the point of project approval, and thus end of ESRI process, is not clear. For example, in the case above some of the tasks were bootlegged, done under the impetus of one individual and it is not clear whether it was centrally approved or not. Interviewees revealed meetings during the course of this innovation were rarely formal, instead undertaken without clear agenda items or written outcomes. More often instruction appeared to take the impetus of ‘do what you can when you can around your day to day responsibilities‘, rather than official time allocation even on reaching NPD status. This creates some ambiguity around the transition point from ‘project phase’ to NPD status. Activities and goals undertaken at this time equally resemble informal group engagement by a ‘project broker’ as official project team leadership.

The case above is further complicated as the same individual played the role of Boundary Spanner, Gate Keeper and Project Broker who also happens to be a son of the owner. In summary, a problematic issue arises in clarifying the Project phase conclusion within SMEs. Pre-project approval activities and post-project approval activities may be hard to distinguish.

In light of this problematic juncture we draw attention to retrospective interviews as a notable limitation, important details and nuances may be lost to poor memory recall. It is expected some of the difficulties faced here will be mitigated by the proposed think aloud research protocol as it concurrently reports on activities and offers more immediate verbalisation which is more accurate and detailed (Ericsson & Simon, 1980). In order to unequivocally resolve this, we recommend it is clarified between subject and interviewer before concluding the research experiment.

Our findings support two key variables which bound the initial problem space. These recognise legacy organisation attributes, in particular existing markets and capabilities, and attributes of the individual, in particular their knowledge base be it of technology or market type. In an uncertain problem space an organisational layer bounds an employees thinking at the start. Khurana and Rosenthal’s ‘Holistic front end’ and Hambrick’s ‘field of vision’ offer theoretical grounds for measurement of both individual and organisational influences on cognition. Finally, this study supports the important and relevant issue of individual positioning in networks at the boundary spanning interface. For example, we know in the case above the individual participated in both academic technology networks and interfaced with end customers at trade shows. This, along with the individuals absorptive capacity (Cohen & Levinthal, 1990), proved a significant driver in the resulting radical innovation outcome

Conclusions

In conclusion, this study sets out a novel experimental protocol and framework for future investigation of design thinking and early stage radical innovation by contributing three elements. It empirically supports a process model for radical innovation. Secondly, it characterises the environment of the radical innovation problem space. Thirdly, it offers a taxonomy of cognitive behaviours to be observed in ESRI.

References

Bamford, G. (2002). From Analysis/Synthesis to Conjecture/Analysis: a Review of Karl Popper's Influence on Design Methodology in Architecture. *Design Studies, 23*(3), 245 - 261.

Bessant, J., & Tidd, J. (2007). *Innovation and entrepreneurship*: John Wiley & Sons.

Bousbaci, R. (2008). "Models of Man" in Design Thinking: The "Bounded Rationality" Episode. *Design Issues, 24*(4), 15.

Brentani, U., & Reid, S. E. (2012). The Fuzzy Front-End of Discontinuous Innovation: Insights for Research and Management. [Article]. *Journal of Product Innovation Management, 29*(1), 70-87. doi: 10.1111/j.1540-5885.2011.00879.x

Buxton, B. (2007). Sketching User Experiences; getting the design right and the right design. 445.

Camillus, J. C. (2008). Strategy as Wicked Problem. *Harvard business Review*(May), 9.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly, 35*(1), 128-152. doi: 10.2307/2393553

D'Aveni, R. A. (1999). Strategic Supremacy through Disruption and Dominance. [Article]. *Sloan Management Review, 40*(3), 127-135.

Ericsson, K. A., & Simon, H. A. (1980). Verbal Reports as Data. *Psychological Review, 87*(3), 37.

Hambrick, D. C., & Mason, P. A. (1984). Upper Echelons: The Organization as a Reflection of Its Top Managers. *The Academy of Management Review, 9*(2), 193-206. doi: 10.2307/258434

Khurana, A., & Rosenthal, S. R. (1998). Towards holistic "front ends" in new product development. *Journal of Product Innovation Management, 15*(1), 57-74. doi: http://dx.doi.org/10.1016/S0737-6782(97)00066-0

Kim, J., & Wilemon, D. (2002). Focusing the fuzzy front–end in new product development. *R&D Management, 32*(4), 269-279. doi: 10.1111/1467-9310.00259

Kim, W. C., & Mauborgne, R. (2004). BLUE OCEAN STRATEGY. [Article]. *Harvard Business Review, 82*(10), 76-84.

Kim, W. C., & Mauborgne, R. (2005). Blue Ocean Strategy: FROM THEORY TO PRACTICE. [Article]. *California Management Review, 47*(3), 105-121.

Kim, W. C., & Mauborgne, R. (2005). *Blue ocean strategy: How to create uncontested market space and make competition irrelevant*: Harvard Business Press.

Kotler, P., & Rath, G. A. (1984). DESIGN: A POWERFUL BUT NEGLECTED STRATEGIC TOOL. [Article]. *Journal of Business Strategy, 5*(2), 16.

Liedtka, J. (2000). In Defense of Strategy as Design. [Article]. *California Management Review, 42*(3), 8-30.

Lindberg, T., Gumienny, R., Jobst, B., & Meinel, C. (2010). Is there a need for a Design thinking Process? *DTRS8*, 243-254.

March, J. G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science, 2*(1), 71-87.

Marren, P. (2010). Alternative strategies; Nailing strategic jello to the wall. *Journal of Business Strategy, 31*(3), 3.

Martin, R. (2009). The Design of Business; why design thinking is the next competitive advantage.

McDermott, C. M., & O'Connor, G. C. (1999). Managing Radical Innovation: An Overview of Emergent Strategy Issues. *The Journal of Product Innovation, 19*, 15.

Mintzberg, H. (1978). Patterns in Strategy Formation. *Management Science, 24*(9), 934-948.

Mintzberg, H. (1994). The Fall and Rise of Strategic Planning. [94107]. *Harvard Business Review*(Jan-Feb), 8.

Moghaddam, A. (2006). Coding issues in grounded theory. *Issues in Educational Research, 16*(1), 52-66.

Norman, D. A., & Verganti, R. (2013). Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change. *Design Issues, 30*(1), 78-96. doi: 10.1162/DESI_a_00250

Reid, S. E., & De Brentani, U. (2004). The Fuzzy Front End of New Product Development for Discontinuous Innovations: A Theoretical Model. *Journal of Product Innovation Management, 21*(3), 170-184. doi: 10.1111/j.0737-6782.2004.00068.x

Rittel, H. (1973). Dilemmas in a General Theory of Planning*. *Policy Sciences, 4*, 15.

Sarasvathy, D. (1997). *How do firms come to be? Towards a theory of the entrepreneurial process*. Paper presented at the Frontiers of Entrepreneurship Research.

Sarasvathy, D., Simon, H. A., & Lave, L. (1998). Perceiving and managing business risks: Differences between entrepreneurs and bankers. *Journal of economic behavior & organization, 33*(2), 207-225.

Sarasvathy, S. D. (2001). Causation and Effectuation: Toward a Theoretical Shift from Economic Inevitability to Entrepreneurial Contingency. *The Academy of Management Review, 26*(2), 243-263.

Sarasvathy, S. D. (2009). *Effectuation: Elements of entrepreneurial expertise*: Edward Elgar Publishing.

Sarasvathy, S. D., Dew, N., Read, S., & Wiltbank, R. (2001). Effectual entrepreneurial expertise: Existence and bounds: Citeseer.

Schon, D. A. (1991). The Reflective Practitioner; how professionals think in action.

Simon, H. A. (1985). The Sciences of the Artificial. 229.

Smith, P. G., & Reinertsen, D. G. (1991). *Developing products in half the time*: Van Nostrand Reinhold New York.

van Aken, J. E. (2004). Management Research Based on the Paradigm of the Design Sciences: The Quest for Field-Tested and Grounded Technological Rules. [Article]. *Journal of Management Studies, 41*(2), 219-246. doi: 10.1111/j.1467-6486.2004.00430.x

Verganti, R. (2009). Design-Driven Innovation; changing the rules of competition by radically innovating what things mean. 269.

Zhou, K. Z., & Wu, F. (2010). Technological capability, strategic flexibility, and product innovation. [Article]. *Strategic Management Journal, 31*(5), 547-561.