

How Radical Innovation emerges in Complex Adaptive Systems

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Abstract: The origins of radical innovation are not well understood. Described as the “fuzzy front end”, successful innovation is typically recognised only in hindsight, obscuring the process through which it emerged. Sarasvathy’s (2001) and later work on effectuation shows clear patterns in how successful entrepreneurs think, but offers few details on how they learned to defy conventional wisdom in management theory. This paper draws on a co-produced auto ethnographical study of how 8 student teams in Higher Education delivered radically innovative products (products unlike anything currently on offer). It draws on education theory and neuroscience, specifically *situated cognition* and the *learning paradox* arguing that radical innovation emerges in co-creation through interactions between cognitively diverse people in a complex adaptive system. Its key contributions are to add more detail to the effectual process and fill some of the gap between theory and practice..

Keywords: Radical Innovation; creativity; effectuation; complex adaptive system; situated cognition; higher education

1 The paradox of the “Fuzzy Front End”

The origins of radical innovations are not well understood. Most successful *breakthrough* innovation is recognised only in hindsight (Moran, 2009), making study of the process difficult. Sarasvathy’s (2001) work on effectuation shows clear patterns in the way successful entrepreneurs think, but offers few insights on how these entrepreneurs learned their trade, particularly as effectual logic runs counter to the conventional wisdom of management theory. Education theorists argue that radical creativity (coming up with something completely new) is not possible because cognition is situated in practice. To conceive of something completely outside that practice creates a *learning paradox* (Boom, 1991) – a circularity in which, to learn something new you need to know where to look for guidance, but if you know where to look, it cannot be new (Fodor, 1980). Boom’s (1991) and Bereiter’s (1997) resolutions to this paradox propose cognitive diversity achieved through trans-disciplinary working. Their methods largely apply to transcendent concepts, (p-creativity) – adapting someone else’s practice a to your own. For h-creativity – developing something entirely new, appears to require emergence (Sawyer, 2003), a theoretical construct of complex adaptive systems (CAS).

This paper examines how radical innovation emerges in a CAS. It builds on *effectual reasoning* arguing that radical innovation results from entrepreneurs seeking outcomes sufficiently better to attract customers. These customers emerge effectually, self-defining

through the process, creating a *motivated market* (Neild, 2023) so invested in the outcome that they help the innovator develop it. Interactions between agents in this motivated market drive the initial idea into a product that presents a sufficiently valuable and appropriate alternative to current offerings that customers will switch. The product's value drives motivation to adopt, while its appropriateness reduces resistance to change. Both factors help the new product become the obvious choice for prospective consumers.

The research studies students' final year projects, plans for innovative new ventures, assessed on their impact and the evidence puts forward to support it. Eight projects were researched alongside 80 process reflections, which described students' key learnings from the course of study. Two cases are included in this paper.

Defining Radical Innovation

Radical innovation, *breakthrough* innovation and *disruptive* innovation are often used interchangeably. Norman and Verganti (2014) argue “no radical innovation was ever designed”, distinguishing between *incremental innovation* “doing better what we already do” and *radical innovation* “doing what we did not do before” (p82). This accords with the cognitive distinction between *relative learning*:

“the accumulation of (propositional) knowledge within a given conceptual framework”
and *fundamental learning*:

“the development of novel standards or conceptions of rationality.” (Boom, 1991 p86).

Breakthrough innovation, defined as:

“an advance in knowledge, technique, or a successful development” (Datta & Srivastava, 2023 p2) is too generic to be useful.

Disruptive innovation is defined as innovations that start in low-end or new market footholds and spread into the mainstream markets, disrupting the incumbents (Christensesn et al, 2015). Disruption can only be observed in hindsight, although the knowledge that incumbents often leave gaps (niches) for start-ups to exploit offers relief to innovators quick to decry the lack of opportunities left to exploit.

2 Radical innovation - vital but difficult.

Human brains struggle with radical creativity (coming up with ideas never done before) because learning stems from practice, known in cultural psychology as “cultural mediation” (Cole, 1996, p119). *Situated cognition* (knowledge embedded in the activity, context, and culture of its creation) conspires against fundamental learning. Neuroplasticity research shows the brain reinforces neural pathways for frequently recurring activities while pruning synapses not triggered, a process persisting well into adulthood (Tierney & Nelson, 2009). Usually this serves us well; improving tasks regularly practiced, but it hinders creativity. The further we deviate from our experience, the more fallible our judgement becomes (Tversky & Kahneman, 1974).

Unfortunately, consumers' brains similarly conspire against change. Neuroscience shows that perception through senses (sight, smell, hearing and touch) is not an accurate

reflection of sensory stimuli, but an intuitive representation of them (Volz & von Cramon, 2006). Intuition is heavily influenced by experience; we see what we expect to see rather than what is really there. Intuitive perception is experienced through optical illusions and seeing things that on second glance turn out not to be what was expected. The implication for innovation is that half of new products fail, not for offering poor value, but because customers don't intuitively see it (Simester, 2016).

Cognitive difficulties exacerbate the conventional wisdom of classical economics, which treats people as homogeneous rational actors intent on maximising their utility in predictable ways. Reality is messier, which explains why, despite encouragement from *Lean Start-up* to validate ideas with customers, many start-ups fail due to *no market* for their products (CB Insights, 2020). Hypothesis validation helps with incremental innovation, but not for products too new for customers to know enough to consider them.

We need radical innovation.

Today the need for radical innovation is acute. Our current trajectory is not sustainable. Climate crises, societal discontent and technological acceleration cited in the World Economic Forum's 2024 risks report have hiked anxiety sharply since 2023. We need to change current practices and do what we have not done before.

3 The study

CB Insights and others' data inspired the study. Innovative entrepreneurs are not stupid, so *why do they so consistently develop products that customers don't buy?* Answering required a different approach. Defining success in innovation in terms of adoption forces us ask what is needed for customers to adopt new products. Novelty is insufficient to *cross the chasm* Moore (2014). The pragmatism of the *early majority* demands results, a position supported by definitions of creativity. Novelty is not in itself creative, appropriateness or meaningfulness are equally important (Bruner, 1962) and (Runco & Jaeger 2012). Persuading customers to switch away from current practice and embrace the new requires that innovative products are obviously better for the user context.

How do we consistently achieve this?

Research question.

What teachable process enables entrepreneurs to develop innovative products that customers don't know to look for, but when they see them, quickly recognise them as the obvious choice for their needs?

Research design:

The study was practitioner research undertaken while teaching in HE. Students worked up plans for innovative new ventures, assessed on their likely impact, feasibility and the evidence for their claim. Students reflected on the approach they used, noting the factors most affecting their progress. Assessed on critical reasoning, an average reflection describes the process or tools used, while excellent reflections analyse strengths and

weaknesses of their approach, supporting their arguments with literature often beyond the taught content.

Data

Eight venture reports were studied, all assessed as first-class. Seven of them remain successful businesses, students from the 8th opting for employment over bootstrapping a social venture. Two are included as case studies here. 40 randomly selected individual reflections were also analysed, supplemented with supervision and mentoring notes.

Methods and methodology

Practitioner Research covers different approaches to data gathering analysis and interpretation. Important was to understand the process through the eyes of the students who lack my years of experience and whose formative years laid a very different foundation. The study examined the early-stage innovation process through five lenses:

1. A world view socially constructed between innovators and their prospective customers. The alignment in their views indicated the effectiveness of communication, studied using ethnographic methods seeking the subjective views of each party and how intersubjectivity helped alignment.
2. How trans-disciplinary teams harness cognitive diversity to develop a venture. Individual reflections highlight the challenges of effective team working and the approaches that most effectively helped them.
3. A phenomenological lens noted the challenges of making sense of inadequate and contradictory data, studying entrepreneurship through practice rather than third-party accounts written in hindsight. Innovation has no objectively correct answer, but rather a best contextual fit. This was conceptually confusing for students from a STEM background.
4. In an auto-ethnographical view, I share my key epiphanies (Ellis et al., 2011) from literature and student activity, relating them to my experiences of innovators challenges built up over many years as practitioner of both innovation and teaching adult learners.
5. Finally, a complex adaptive system perspective (proposed by a student) offered a useful analytical framework for interactions and experiments with feedback loops. Complexity theory explains how to optimise those interactions to influence emergence towards a useful outcome.

All five are co-produced as most of the data was produced by students in response to teaching provocations and their experiences of participatory research with prospective customers. Analysis and interpretation is necessarily my own as required by a doctoral thesis.

4 Findings:

The study found that:

All the ventures studied used an effectual process, some more consciously than others. Most founders were driven by a strong purpose driven by lived experience of the problem they were addressing. Final solutions emerged in co-creation with prospective customers self-selecting driven by a desire to help bring the prospective product to market. This provides early evidence of traction.

1. For innovative products to be quickly adopted by their intended users, requires them to be both valuable and appropriate to the customers' situation. Value provides the motivation for customers to change behaviour and adopt a better way of being. Appropriateness minimises the cognitive and cultural distance the customer needs to traverse to derive value from the product. An appropriate product conforms closely to the world view of the intended user minimising adoption friction.
2. Valuable and appropriate radical innovation emerges through interactions in a complex adaptive system. Through these interactions, innovators discover cultural *attractors* within a self-selected 'segment' that represent entrepreneurial opportunities to co-create new markets by facilitating cognitive alignment around an emerging cultural norm (Falandays & Smaldino, 2022).
3. Meta-cognitive skills (learning how to learn) powered Transformational Learning. Effectual, co-creation and team-working skills (psychological safety) enabled the effective harnessing of cognitive diversity to blend different experiences into new and valuable opportunities.

A more detailed discussion of these findings follows.

Co-creating the problem.

Nascent innovators using creative problem-solving techniques typically rush through the challenge of discovering the real problem¹. Problem solving is practised during schooling, whereas problem definition is not. Thus, young adults rarely question whether it is the right problem, so keen are they to solve it. Divergent thinking techniques like the "five-whys" get to the root cause of a problem by repeatedly asking why?². By the fifth *why?* the root cause problem is so different from the original context that it escapes situatedness, reducing the cognitive distance to a radically creative outcome.

Unfortunately, this is rarely as simple as presented here.

The invisibility of habit

The roots of human habits often lie in long forgotten experiences unique to the individual. Asking research participants why they do certain things is often met with a quizzical shrug intimating "It's obvious!", revealing how rarely people question custom and practice. Tacit practice (van Houten, 2023), sometimes referred to as *second nature* is

¹ Mauraya discusses this further at: <https://www.leanfoundry.com/articles/love-the-problem-not-your-solution>

² An excellent illustration of this technique is here: https://youtu.be/N7cR2gArCFE?si=l_NPJyw1ztChCnfp

both invisible and obvious to individuals. We just do it. To others, it is neither. Vygotsky (1978) describes these as *everyday concepts* noting that their lack of common patterns makes explaining them to others difficult.

Different people gazing at an object may agree on its explicit (objective) attributes such as colour, weight and shape, but fundamentally disagree on its tacit (subjective) attributes such as value and appropriateness to individual needs. Making assumptions about people based on objective criteria inevitably leads to trouble, but hidden subjectivities require effort to make explicit. Co-creation proves incredibly useful here. With non-physical products such as media or services, the challenge becomes more acute as the following case study shows.

Young adults seem increasingly susceptible to mental health “issues”. Two students were keen on tackling mental health as they had lived experience of the debilitating effects it can have. *Why did problems persist given the market leader?³ Why were students not engaging with it?* Co-creative research revealed that the stigma of “issues” (the word signified a sense of personal failure) put people off. Reframing the problem away from mental health issues, through mental wellbeing and on to mental fitness substantially improved engagement. The group understood the benefits of physical fitness, mental fitness was no great cognitive leap, empowering far more positive engagement. This example of reframing through convergent thinking took several weeks of patient discussion and only happened when once suggested others quickly agreed. This shows the power of co-creation. Neild (2022) sets out a detailed description of how students in this study used it successfully, arguing that effective co-creation requires five factors:

1. Power symmetry – enabling all participants to shape the direction of the project.
2. Embracing subjectivity and bias
3. Relational rather than transactional interactions
4. Abundance mindset– maximising value for all, rather than individual shares
5. Harnessing intrinsic not extrinsic motivation

The depth of insights gained through co-creative research are rarely obtainable from secondary sources and easy to miss in interviews because of their tacit and often personal nature. But in a trusted environment of peers with psychological safety and intrinsic motivation to seek a better way of being, deeper insights emerge. The mechanism is discussed in the next section.

A problem definition co-created with a representative sample of potential customers, provides a better early indication of product-market fit than *lean start-up style validation*, good progress given that around half of all products launched by leading companies fail to achieve it (Victory et al., 2021).

Developing a valuable and appropriate solution that addresses the identified problem begins here.

³ Most were aware of “Headspace” – a meditation application. But it did not offer what they hoped.

Complexity and emergence

Sarasvathy's (2001) ethnographic study on the process followed by successful entrepreneurs supports an emergent view of innovation. Her findings uncovered a logic based on *contingency* (start with resources immediately to hand) and *locality* (work with the most accessible people) that *carefully manages risk* (risk only what you can afford to lose). Entrepreneurs start with no organisation, no resources or relationships to lean on. This *effectual logic* explains a seemingly random process. Driven by a lack of resources and no clear market demand (for a product yet to exist), entrepreneurs in her study were unable to follow a typical management causal process in which the end is defined, and the means acquired from the surrounding organisation to achieve it. Instead, by starting with the means at hand, (skills and relationships), entrepreneurs allow the end to emerge, contingent on the support and resources they most easily obtain. Entrepreneurial innovators face similar challenges, with limited resources and no indication of demand for a product idea until a "problem worth solving" emerges.

Innovation emergence contrasts with a Darwinian process of natural selection. Instead of random variation caused by accidental genetic mutation, entrepreneurs deliberately adapt their ideas to fit with the external environment in a *Complex Adaptive System (CAS)*. A CAS has four interesting features which the cases also exhibited:

1. The trajectory cannot be predicted from the initial conditions because the possible interactions within the system that influence its future direction are too numerous to model – what emerges is original and surprising. Complexity arises because, contrary to neo-classical economics, humans are neither rational, nor are their behaviours reducible to predictable utility maximisation theories (Simon, 1955).
2. Adaptation follows feedback. Innovators deliberately incorporate feedback into their prototypes, pushing adaptations back out for further feedback to optimise product-market fit.
3. The rate of adaptation must be regulated or the system spirals into chaos. Conversational turn-taking and valuing individual input regulates the rate as new agreements are reached. Too much divergence rapidly becomes overwhelming, so a common purpose or agreed outcome is vital.
4. Finally, emergence is a feature of a CAS. When independent agents interact around a common topic, a consensus emerges, which no individual could predict, but all broadly agree on. Innovators want this birth of a brand-new market.

5 Driving the emergence of radical innovation.

Can emergence be driven?

Cultural evolution literature describes *attractors* as the states to which CAS tend (Falandays & Smaldino, 2022). In natural selection, *attractors* define what characterises the "fittest" engendering its survival; in cultural selection, a similar process is at work (Mesoudi, 2021) except that innovators drive the feedback loops as described above (Galkina & Atkova, 2020). Innovators do not define attractors; but facilitate consensus. A

group of cognitively diverse individuals united by a common desire to solve a specific problem creates a *motivated market* (Neild, 2023). Peequal found enough women sufficiently motivated to reduce queuing times for their toilet. Remap (the mental fitness case study described earlier) similarly found enough people motivated to improve mental fitness. In both cases, people were willing to share intimate and personal details intrinsically motivated by the promise of a better life. Entrepreneurs orchestrate the emergence of both a motivated market and new products to satisfy its desires. Contrary to some views in innovation (Sarasvathy et al., 2003), entrepreneurs do not define or create a market, but instead facilitate convergence around a consensus definition.

Participants in a *motivated market* self-select into it (Neild, 2023b) creating a deliberately biased sample.

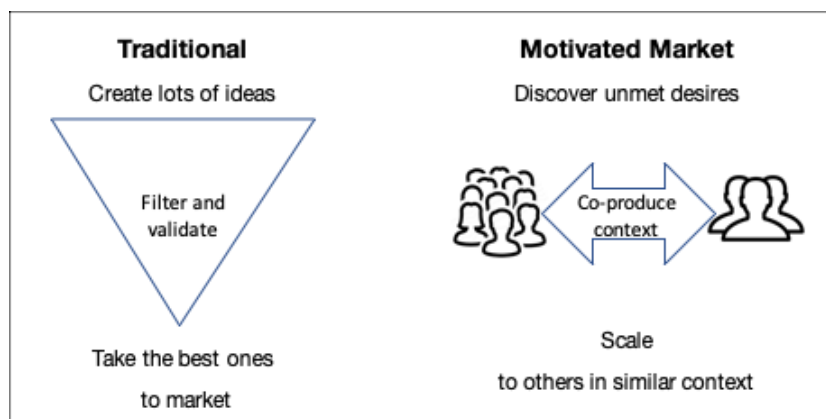


Figure 1: *Motivated Market* (Neild, 2023)

Academic research seeks broadly generalisable knowledge; Innovation research seeks a widespread bias that a problem is worth solving, (Mauraya, 2018) which constitutes a new market opportunity. In our cases, student groups assembled looking for interesting ideas to progress into projects. Effectual (authentic) high-level topic areas represent problems or opportunities, where they have means at hand. Conversations among their contacts reveal which topic areas resonate. They may use a social media survey to reach more people and gather some preliminary data on general preferences (useful for market sizing), and then invite willing respondents to offer more detailed insights by opting in to ongoing participation. Structured surveys do not offer deep insights, limited as they are to the questions the researcher asked (Queiros et al, 2017). Semi-structured interviews and observations enable discovery of areas that may not have occurred to the researcher, helping them explore beyond boundaries imposed by previous experience. This is the beginning of the co-creation process as insights from participants increasingly shape the research process as illustrated in Figure 2.

Community Engagement / Primary Research Plan

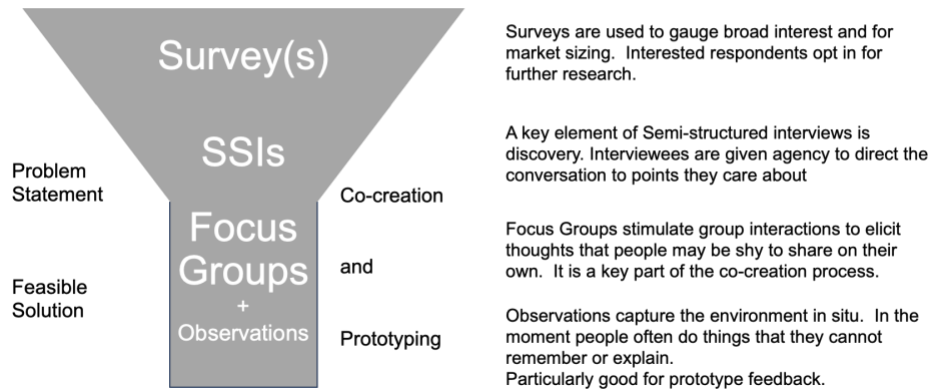


Figure 2: Eliciting the emergence of radical creativity.

Attracting cognitive alignment

Sarasvathy's (2001) work distinguishes between predicting the future and creating it, arguing that successful innovators do the latter because the former is notoriously difficult. The study findings highlighted the importance of appropriateness and value to maximise adoption, which suggests that not every idea can become an attractor. There needs to be some mutually beneficial symbiosis between the outer environment (including culture) and the idea before it can start to drive the direction of emergence. The problem needs to resonate with its intended audience before cultural evolution can occur. This suggests that the process of creative innovation is a combination of both the discovery and creation of opportunities, supporting a study examining entrepreneurship as information processing (Vaghely & Julien, 2010). So, innovation behaves like a CAS because its adoption depends on cultural evolution. For a brand-new product to be culturally appropriate and thus understood in a culturally mediated world, culture needs to change in step with the emerging product.

Previous work on cultural evolution includes the role innovation plays in driving it, illustrative examples of which include (Tomasello, 1999) and (Mesoudi, 2021). Similarly, the role of cultural attractors in driving cultural evolution is well documented (Falandays & Smaldino, 2022), but the literature is sparse in describing how cultural attractors cause innovation to emerge. Instead, based on the properties of CAS, the nature of emergence within them and the case study evidence of how student innovators bring about cultural change, I propose the CAS model described in this paper for the emergence of radical innovation. Adapting Mesoudi's (2021) process of *cultural selection*, intentional agents (in a *motivated market*) deliberately select more beneficial variants, propelling cultural evolution. For example, in scarcely a human biological generation the meaning of the signifier 'telephone' has evolved from a tethered single function voice communication device to an untethered (mobile) device capable of thousands of functions, with voice calls diminishing in significance. This is cultural evolution at work and shows how quickly our ways of being can change given the right innovation.

Co-creating value and appropriateness.

What factors make innovation bring about such a large-scale behaviour shift? Transformative innovation offers tangible benefits (value); appropriate innovation makes sense to us. We appreciate innovation that makes those benefits obvious in the contexts and situations of our everyday lives. Often, innovation needs to reframe a product to make it meaningful (Norman & Verganti, 2014). Henry Ford's genius in the early 20th Century was to reframe the meaning of car from being a rich person's plaything to a working person's tool. Realising this reframing drove a radical innovation in manufacturing, the production line, to make cars affordable. A century later, Elon Musk's perceived genius was to reframe electric cars from the humble golf buggy to exciting high-performance cars. Nobody bought a Toyota Prius because it was fun or sporty, but when Tesla showed that electric vehicles could be the fastest production car in the world, even confirmed "petrol heads" took notice, bringing with them, high-end car makers. Radical innovation achieves impact when it helps enough people achieve what they desire yet struggle to accomplish. So, how do we assure value and appropriateness?

Gen Z (digital nomads) social lives exist in a CAS. At any one time they can be interacting with multiple sub-groups, relating in various capacities with family, people they study with, people they live with, and those with whom they pursue leisure activities. These groups are all self-selecting: people opt in to them. A motivated market is just the same. It is simply a group that choose to interact with others that share a special interest. This might be an aspiration or "job to be done" (Klement, 2018) rather than the demographic segmentation (eg age or income bracket) traditionally used by marketing firms. In line with effectual reasoning, entrepreneurs float ideas through social groups to see which ones resonate. They start off quite broad, but over time cognitive alignment occurs because the random choice of phrasing caused by the diversity of participants' backgrounds starts to converge as they collectively share a common reference frame or *intersubjectivity*. Innovators push for intersubjectivity by expressing a common intrinsic motivator and then probe for specific signs and signifiers that provoke the optimal feedback. In the case of Peequal, participants initially disliked the term urinal because it symbolised male dominance in toilet design. Over time though as they started to understand how the product work; they saw a female only urinal as representing equality. For Remap, discovering that mental fitness resonated much better with their intended audience (and their emerging product) than dealing with *issues* proved to be instrumental in attracting initial customers. Both cases show how important semiotics can be for a radically creative concept to be perceived as appropriate. Shared meanings emerge when group members clumsily or evocatively express similar sentiments until the group starts to converge around the signifiers that resonate. These emergent signifiers (words, pictures or actions) are not the natural starting point for participants, but are adopted in preference to the original. Thus, new meanings emerge and self-reinforce within the group until the group collectively adopting a common parlance. By encouraging the use of prototypes, visual and activity-based interactions surface different dimensions of meaning. At the simplest (low fidelity) level, prototypes might be basic drawings. They gain sophistication through the process as the group aligns on the feature set becoming (high fidelity) detailed simulations of the user experience in interacting with the prototypes to optimise the user interface.

6 Contribution:

The paper aims to reduce the fuzziness at the front end of innovation by showing the genesis of innovative opportunities and enhance Innovation Resistance Theory, demonstrating how co-creation with prospective customers develops cognitive alignment, increasing the rate of adoption. It supports and adds detail to effectual reasoning as the cognitive process by which entrepreneurs develop new opportunities. Finally, it proposes a model of complex adaptive systems driving interactions between cognitively diverse tribes of prospective customers motivated by the chance to achieve a desired outcome.

7 Practical implications:

This paper provides useful insights for innovation educators and practitioners on the process of developing innovative products that new customers will adopt with alacrity. Around 50% of new products fail in the marketplace, start-ups are similarly unsuccessful. A primary reason for start-up failure is that there is no market need for the product developed. The paper shows how innovators ensure “product-market fit” and evidence early traction, which may be of particular interest to the funding community. Innovation is also required to tackle climate change.

The research illustrates how young people can be particularly good at delivering innovation because they are less set in their ways. Subject Matter Expertise supports incremental innovation but impedes radical innovation because radical innovation necessarily comes from outside communities of practice. This has significant implications for top-down Government led innovation projects and helps explain why so many fail.

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