Motivation as a Major Direction for Design Creativity Research

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Abstract. This paper views products of designing as outcomes of the effects of knowledge (i.e. product knowledge) and flexibility (i.e. process knowledge, with which to structure and modify product knowledge), both of which influence and are influenced by motivation. While knowledge aspects received substantial attention in the past, motivation received far less attention. This paper argues that design creativity research should focus on this area: identify major motivational factors, their relationships, and how they affect design creativity, and how this understanding could be used to enhance creativity education and practice.

Keywords: Design creativity, motivation, creative lineages, milieus, individuals

1 Introduction

In his famous bestseller "Outliers", Malcolm Gladwell [Gladwell, 2008], identifies the broad influences on what makes people successful, which could be classified into: ability, opportunity, and effort. Taking examples of people from diverse areas such as Beatles in music, Bill Gates in business, or Joe Flom in law, he argues that while ability is an essential ingredient for success, opportunity (e.g. having the right, exclusive computational facility at the Lakeside school in Seattle where Bill Gates studied; the opportunity of Gates to work on these computers for long hours at the school; or being born at such as an age at which he was among the very few who would be at the right age to have the possibility to take advantage of a potential PC revolution) plays a significant role. Also, it is crucial, Gladwell argues, to have put in substantial effort, in his estimate about 10,000 hours, into preparing for and working towards exploiting the opportunity.

Inspired by the work of [Lewis, 1981], we had earlier proposed three broad baskets of factors that might be responsible for design creativity: knowledge, flexibility and motivation [Chakrabarti, 2006]:

- Knowledge: this refers to the product knowledge of the creative agent under focus, e.g. knowledge of how devices work, phenomena happen, etc;
- Flexibility: this refers to the process knowledge of the creative agent under focus – knowledge using which product knowledge is processed;
- Motivation: this refers to the factors that influence the amount of effort the agent puts in to develop and actualise product and process knowledge.

Taking the common definition of design creativity as the "ability or process of developing novel and useful ideas, solutions or products" [Sarkar and Chakrabarti, 2007], and taking the view that the three broad influences on success – ability, opportunity and effort, will also influence the usefulness of a product, we see that only two of the three influences are addressed by the three proposed baskets of factors. While creative ability in design comprises knowledge of two kinds – product and process, the effort that will be spent into developing and actualizing this ability is influenced by both knowledge and motivation. The baskets of factors do not seem to have much influence on opportunity, examples of which in the case of Bill Gates might be: affluence of his parents to put him in the Lakeside school where only the most privileged could join, or the opportunity that arose due to development in 1975 of a minicomputer kit called Altair 8800, the year Bill Gates turned 21 – the right age to take advantage of the resulting PC revolution. The realm of design creativity research, therefore, can encompass factors that could potentially affect two of the above three influences: *ability* and *effort*, with opportunity largely remaining out of bounds. Three points are noted about these baskets of factors:

- Both product and process knowledge and their actualisation are essential for design creativity;
- Motivation helps develop as well as actualise these knowledge types;
- The relationships between motivation and knowledge are synergistic – having motivation helps development and actualisation of knowledge, while having knowledge helps motivation for its (further) development and

actualisation. The negative effects, of not having motivation or knowledge, are also synergistic.

2 Motivation as a research direction

Current research into creativity primarily focuses on definitions and measures of creativity, and on processes of ideation and their support. For instance, there is a large variety of definitions of creativity, its various components, and how to measure creativity, see [Sarkar, 2007] for a compilation. There is extensive work on understanding the product, process and ability aspects of creativity, i.e., what parameters in the product, process or ability of an agent or a group of agents relate to creativity [e.g. Davies, 1999]. Also, a variety of methods for enhancing various aspects of creativity, mainly ideation, have been developed, e.g. Brainstorming [Osborn, 1963], Synectics [Prince, 1970], or TRIZ [Terninko et al., 1998]. Analyzing current work on creativity from the viewpoint of the three major influences – product knowledge, process knowledge, and motivation for developing and actualising these, we see that while some aspects of product and process knowledge have been researched in depth, motivational factors for design creativity, are much less investigated. Motivational factors, therefore, form the research direction in design creativity research that we wish to propose in this paper.

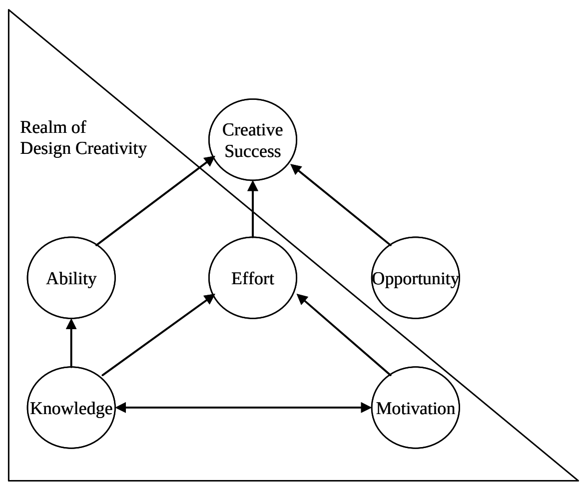

Fig. 1. Factors influencing creative success

2.1 Internal or External Reward or Punishment

We identify two broad groups of motivational factors: motivation for *external reward (or against internal punishment)*, and motiavtion for *internal reward (or against internal punishment)*. With inspiration from Abraham Maslow's pyramid expressing hierarchy of human needs [Maslow, 1954], we take these two as increasingly more refined motivations for action.

We start at the first level: motivation for or against internal reward or punishment. If reward and punishment are taken as the two extremes of the same scale, this category can be referred to as *motivation for internal reward*. Three broad elements are proposed, which by no means are exhaustive: fulfilment of *curiosity* (e.g. Can that be achieved?), fulfilment of *ideals* (e.g. I want to save the planet), or taking up *challenge* (Let us see if we can achieve that).

At the second level, motivation is fuelled by external rewards: recognition/fame, wealth/money, power/influence, social-life/companionship/love, etc.

As in Maslow's pyramid, motivations may well start at the lower level, and go to the higher level as the needs in the lower level are already fulfilled.

Saunders and Gero [2001] speak of curiosity as a major motivational force in creativity. Curosity is seen as a trait that derives pleasure from fulfilment, and shifts focus to something else to continue with this pleasure-deriving activity. Anecdotal literature is replete with references to curiosity, e.g., Feynman [Feynman, 1985] speaks about his childhood being curious of how nature works. The story of George de Mestral [Website1, abbreviateed WS1] – inventor of Velcro [WS2] – is well-known for how his curiosity got the better of his irritation, to find how the burdock burrs that kept sticking to his clothes and his dog's furs during a hunting trip to the Alps in 1941 clung so well to fabric, which led to the invention of Velcro.

Fulfilment of ideals could also be seen as a major motivation. The work of Karl Marx, for instance, was driven strongly by his ideals of social equity. Many artists, e.g. Gauguin [WS3], Mondrian [WS4], or Klee [WS5] had been driven by strong ideals. Gauguin was drawn to primitivism in his endeavour to reach beauty in its purest form untouched by civilization; Mondrian strove for basic forms of beauty through his use of simple, monochromatic, geometric shapes; or Klee's works of art had been driven by his urge to evoke spirituality. In engineering, Alec Issigonis [WS6] have been driven by his "hate for large cars", a prime internal motivation for developing his most famous design Morris Minor "Mini".

The third source of internal motivation proposed is challenge. What the rewards are is a matter of further research: one possibility is the pleasure derived from the fun and excitement of carrying on the challenge, and those associated with the release at the point of succeeding the challenge. Watson – co-discoverer of the double-helix structure of the DNA – was driven by his perceived competition from Linus Pauling in a race to the Nobel Prize for this work [Watson, 1968].

Thomas Alva Edison was quoted as saying “I never did a day's work in my life. It was all fun.” [WS7].

2.2 A Preliminary Model of Motivational Cycle

A preliminary model of motivation called **DisMART** (acronym for **Dis**content-**M**otivation-**A**ction-**R**eward-**T**endency) is proposed below. It is based on the assumption that motivation is influenced by *discontent* – the difference between the perceived current state of things and the state of things as intended by the agent, and the *tendencies* of the agent; a greedy agent may be more affected by lack of wealth than knowledge. The resulting *motivation* – the urge to act, influences *action*, which influences the extent of *reward* or punishment; as a result, both current and intended state of things, as percived by the agent, change, fuelling a new cycle of motivation and action. Reward is influenced also by ability and opportunity, but these are excluded from this model to focus on motivation.

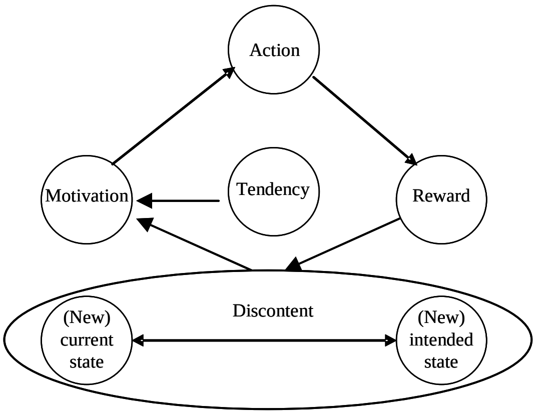

Fig. 2. DisMART Model of motivational cycle

2.3 Research Issues

There is a host of research issues to be asked in the context of design creativity, namely:

- What are the factors that influence motivation?
- What are the relationships among these? For instance, how do external motivations relate to the internal motivations and so on?
- What is the process of rise and fall of motivations? Is there a threshold of something that triggers motivation, satisfaction of which upto a level allowing continuation of motivation, beyond which it may be demotivating?
- What happens if motivations lead to achievement or failure? What is gained or lost as a result?

2.4 Research Approaches

Many approaches could be taken to carry out research in this direction. I propose three, analysis of: creative individuals, creative milieus, and creative lineages.

Not surprisingly, creative individuals have been used often for creativity studies; e.g. Csikszentmihalyi [1997] used this to study societal aspects of creativity; Amabile [1983] used experts in studies on assessing creativity. I propose using information on them in studying motivations for design creativity, with two broad methods: historical case studies of lives of creative designers; and interviews/surveys of creative designers. The two approaches are in somewhat complementary: the former helps analyse lives and work of individuals who are no more, while the latter help analysis of current personalities. The former provides longitudinal studies into the complexities of growth and maturity of the individuals, while the latter help delve deeper into their minds. A combination, where possible, might give a more complete picture.

The second approach is to explore creative milieus to understand the motivating factors. This could be done by identifying the motivational elements valued and nurtured in these environments, and how well these relate to the creative successes of the individuals trained in the environments. In the context of development of modern science, an interesting example is Cambridge University in general, and its Trinity College in particular. As an indicator of scientific creativity, the university had 87 affiliates with Nobel Prize, of which 32 were affiliated to Trinity alone. What did Cambridge do that produced such a staggering number of creative ideas with consistency? Different types of milieus may have to be explored to understand creativity related to design of different types: MIT may be an interesting case to look for technological creativity, while TU Delft may be interesting to study creativity in industrial design.

The third approach is to follow cultural lineage of creative designers – the “Guru-Shishya Parampara” or master-pupil continuity with consistent creativity, and identify what leanings were passed on to ensure this.

3 Preliminary Explorations

We undertake three demnestrative explorations in this section, into the kind of research we propose should be carried out in depth: into creative lineages, on creative milieus, and on creative individuals.

3.1 Creative Lineages

For this exploration, I looked into the lineage of my own PhD supervisor – Thomas P. Bligh – who is an outstanding engineering designer and entrepreneur. Dr. Bligh received a B.Sc. and an MSc in Mechanical Engineering from the University of Witwatersrand, Soth Africa. After 4 years as a senior research engineer in the Mining Research Laboratories of the Chamber of Mines of South Africa, he returned to study for a Ph.D. in Physics on gaseous detonations at very high Pressures and their application to a rock breaking device. In 1972, he joined the Civil Engineering Department of University of Minnesota as an Assistant Professor, and worked on enhanced recovery of oil and gas, geothermal energy and energy conservation in buildings. He proposed the idea of earth sheltered buildings and started the 'Underground Space Centre' to design and research these structures. There are now over 60,000 such houses in the U.S.A. alone. In 1976 he joined the Mechanical Engineering Department at University of Minnesota to work on heat transfer in porous media (i.e. earth) and solar energy; one of his concentrator designs was used in the largest solar heating and cooling project to date. This led to the design and construction of the new earth sheltered Civil and Mineral Engineering Building at University of Minnesota, for which he received the 'Outstanding Engineering Achievement of 1983' award from the American Society of Civil Engineers. By this time he moved to the Mechanical Engineering Department at Massachusetts Institute of Technology as an Associate Professor. He was consultant to U.S. Windpower, who built the first 'wind farm' (of 2000 machines) in California. In 1986, he joined Cambridge University Engineering Department to teach design, and research into design and performance prediction of multi-hulls, design synthesis, and vision-assisted robots for Human Genome programme. Biopik – a vision-assisted robot became the product around which he co-initiated BioRobotics – a start-up in 1990s that became one of the top 20 fastest growing companies in the UK.

Dr. Bligh has a long term interest in underwater photography; he designed and built several underwater cameras, and won numerous awards for his underwater photographs taken using these cameras. He also designed, built and sailed many boats, with a specialist interest in catamarans. In 2000 he launched Lady Bounty - a 14 metre ocean racing/cruising catamaran – built to his own designs. Lady Bounty was launched in the summer of 2000 and caused a sensation when exhibited at the Southampton Boat Show. Since then, a number of production catamarans based on the same design have been completed, including Dazzler, which came first in the 75th Anniversary RORC Non-Stop Round Britain and Ireland Race. Dr. Bligh sailed over 25000 miles on this boat. He retired from Cambridge in 2002, lives in Cornwall, and is an Emeritus Fellow of Gonville & Caius College, Cambridge [WS8].

Exploration of the creative lineages of Dr. Bligh (born 1941) yielded the following. His advisor was Prof. Frank R.N. Nabarro (1916-2006) – a renowned physicist, a Fellow of the Royal Society (FRS), and a pioneer of solid-state physics [WS9]. He worked under Sir Nevill F. Mott (1905-1996) – a Nobel Laureate in Physics in 1977 for work on the electronic structure of magnetic and disordered systems, esp. amorphous semiconductors. Mott [WS10] studied in St John's College, Cambridge under the tutelage of physicist Sir Ralph H. Fowler (1889-1944) [WS11], who supervised 3 Nobel Laureates and 15 FRS. Fowler [WS12-13] had two mentors: Archibald V. Hill and Ernest Rutherford. Lord Rutherford (1871-1937) was a British-New Zealander chemist and physicist [WS14] who became known as the father of nuclear physics, a Nobel laureate in Chemistry in 1908 for his investigations into disintegration of elements, and chemistry of radioactive substances. Hill (1886-1977) was British physiologist and biophysicist who jointly received the 1922 Nobel Prize for Medicine for discoveries concerning the production of heat in muscles [WS17]. Rutherford was a student of Joseph J. Thomson (1856-1940) – a British physicist and 2006 Nobel laureate in physics [WS15-16], who discovered the electron and isotopes, and invented the mass spectrometer. Thomson's advisor was Lord Rayleigh (1842-1919), another Cambridge-based English physicist who received Nobel Prize in physics for co-discovering Argon. He also discovered what are now called Rayleigh scattering and Rayleigh waves [WS18-19].

Lord Rayleigh had two advisors: Edward J. Routh and Sir George G. Stokes [WS20]; both had William Hopkins as an advisor. Stokes (1819-1903) was a mathematician and physicist, who at Cambridge made important contributions to fluid dynamics (e.g. Navier–Stokes equations), optics, and mathematical physics (e.g. Stokes' theorem). He became President of the Royal Society. [WS21]. Edward Routh (1831-1907), an FRS, was an English mathematician – an outstanding coach for students preparing for the Mathematical Tripos examination of Cambridge University, who [WS22] contributed to systematizing the mathematical theory of mechanics and developing modern control systems theory. William Hopkins (1793-1866) was a mathematician and a geologist, and an outstanding teacher with an impressive array of students e.g. Francis Galton and James Clark Maxwell, [WS23]. He made contributed to asserting that a solid forms the interior of the Earth, and was responsible for defining the filed of Physical Geology [WS24].

Advisor to William Hopkins was Adam Sedgwick (1785–1873) [WS25] – one of the founders of modern geology, and an FRS. He had two mentors: Thomas Jones and John Dawson [WS26]. Thomas Jones (1756–1807) was Head Tutor at Trinity and an outstanding teacher of mathematics [WS27]. John Dawson (1734–1820) was both a mathematician and surgeon. He tutored 12 students to become Senior Wranglers (Toppers in Mathematics Tripos Examinations in Cambridge University). He studied the orbit of the moon, corrected serious errors in the calculations of the distance of the earth from the sun, and confirmed an error in Newton's precession calculations [WS28]. Thomas Jones' advisors were Thomas Postlethwaite and John Cranke [WS29]. Postlethwaite (1731–1798) was an English clergyman and Cambridge mathematician, who became Master of Trinity in 1789, and university Vice-Chancellor in 1791 [WS30]. John Cranke (1746-1816), also an English mathematician and clergyman, became a Fellow of Trinity in 1772, and acted as a tutor in mathematics [WS31]. Postlethwaite's advisor, Stephen Whisson (1710-1783) [WS32], was a tutor at Trinity, and coached 72 students in the 1744-1754 period. Advisor to John Cranke is unknown [WS33].

Stephen Wisson's advisor was Walter Taylor (1700-1744) – a Fellow at Trinity who coached 83 students. He was later appointed as the Regius Professor of Greek [WS34-35]. Robert Smith (1689–1768) – advisor to Walter Taylor – was an English mathematician and music theorist, who became Master of Trinity, and Plumian Professor of Astronomy [WS36]. His adviser was Roger Cotes – an English mathematician with an FRS (1682—1716), and advisee of Sir Isaac Newton. He proofread the second edition of Newton's famous book, the Philosophiæ Naturalis Principia Mathematica (Principia). He invented Newton–Cotes formulas and first introduced what is known as Euler's formula. He was the first Plumian Professor at Cambridge [WS37-38].

Cotes' advisor – Sir Isaac Newton (1643–1727) was an English physicist, mathematician, astronomer, and natural philosopher – one of the most influential people in human history. His 1687 publication of the Principia is among the most influential books in the history of science, laying the groundwork for most of classical mechanics. Newton built the first practical reflecting telescope, developed a theory of colour, formulated an empirical law of cooling and studied the speed of sound. In mathematics, he is credited, with Gottfried Leibniz, for developing differential and integral calculus [WS39-40]. He was a Fellow of Trinity, President of the Royal Society, Lucasian Professor at Cambridge, and Master of the Royal Mint.

Newton had two advisors: Benjamin Pulleyn and Isaac Barrow [WS41]. Barrow (1630–1677) was an English mathematician who contributed to the early the development of infinitesimal calculus; discovering the fundamental theorem of calculus. Newton went on to develop calculus in the modern form [WS42]; Barrow was a Fellow and Master of Trinity, and the first Lucasian professor at Cambridge. While his mentor at Cambridge was James Duport, Isaac Barrow learnt mathematics by working under Vincenzio Viviani in Florence, and Gilles Personne de Roberval in Paris [WS43]. Viviani (1622–1703) was an Italian mathematician and scientist, a pupil of Evangelista Torricelli and a disciple of Galileo Galilei. After Torricelli's death, Viviani was appointed to fill his position at the Accademia dell'Arte del Disegno in Florence. In 1660, Viviani and Giovanni Alfonso Borelli conducted an experiment to determine the speed of sound. Timing the difference between seeing the flash and hearing the sound of a cannon shot at a distance, they calculated a value of 350 m/s, considerably better than the previous value of 478 m/s obtained by Pierre Gassendi. In 1661, he experimented with the rotation of pendulums, 190 years before Foucault [WS44]. Viviani's advisor was Galileo di Vincenzo Bonaiuti de' Galilei , or Galileo Galilei, as commonly known [WS45]. Galileo (1564–1642) was an Italian physicist, mathematician, astronomer and philosopher who played a major role in the Scientific Revolution. His achievements include improvements to the telescope and consequent astronomical observations, and support for Copernicanism. Galileo is called 'the father of modern science' [WS46]. The motion of uniformly accelerated objects was studied by Galileo as the subject of kinematics. His contributions to observational astronomy include the telescopic confirmation of the phases of Venus, the discovery of the four largest satellites of Jupiter, and the observation and analysis of sunspots. Galileo also worked in applied science and technology.

Galileo's mentor was Ostilio Ricci (1540–1603) – [WS47] an Italian mathematician and a professor in Florence at the Accademia delle Arti del Disegno. Galileo was enrolled at the University of Pisa, in order to study medicine. Instead, he became more interested in mathematics after meeting Ostilio Ricci [WS48]. Ricci studied under Niccolo' Tartaglia Fontana (1499/1500–1557), who was a mathematician, engineer, surveyor and bookkeeper from the Republic of Venice. He was the first to apply mathematics to investigate the paths of cannonballs, his work later validated by Galileo's studies on falling bodies. He was largely self-taught, which perhaps explains why his mentors could not be traced [WS49-50].

A striking feature of this lineage is the remarkable consistency in the quality of creative outputs of its members. It would be interesting to find out what the messages passed on by the mentors along the lineage have been, and if a consistent set of messages emerge. Some mentors have been outstanding in nurturing students into producing outstanding quality. For instance, Ralph Fowler –mentor of Nabarro – guided a staggering 64 students, of whom 15 have become FRS, and 3 won the Nobel Prize! While the above lineage is mainly of researchers in natural sciences, exploration design creativity should use lineages among designers.

3.2 Creative Milieus

We looked into three very different milieus: all three are identified as important cultures of creativity in [Larsson, 2002]. In Cambridge University - first environment explored – the colleges, the meadows, the river and its long walks seem to play an important role in fostering creativity. One tradition in Cambridge has been to build cultures that promote communication. Max Perutz and Piotr Capitsa – both Cambridge Nobel Laureates – tried to create such environments. As Max Perutz writes in [Larsson, 2002]: "Experience had taught me that laboratories often fail because their scientists never talk to each other. To stimulate the exchange of ideas, we built a canteen where people can chat at morning coffee, lunch and tea…it was a place where people would make friends. Scientific instruments were to be shared, rather than jealously guarded as people's private property; this saved money and also forced people to talk to each other." According to Perutz, "…hierarchical organization, inflexible bureaucratic rules, and mountains of futile paperwork" can kill creativity." According to [Larsson, 2002], "Eagerness for discovery and joy of work thrive at Cambridge." While there is extreme competition, there is also the lure of interacting and working with many creative people. Kapitsa writes [Larsson, 2002]: "When I worked in England, I found the most interesting conversations on the throbbing problems of science were held at college dinners. We used to discuss there problems that embraced many areas of science at one and the same time, and this was the best way of broadening our horizon and of comprehending the current significance of this or that scientific thought." The variety of discussions one can have across disciplines is staggering, as one poet in Cambridge comments [Larsson, 2002]: "At dinner I discuss the latest discoveries of astronomy with one of England's leading physicists, next morning I arrange a poetry reading session with a well-known Kenyan author. Each new meeting inspires my creativity…"

Santiniketan – meaning 'Abode of Peace' in Sanskrit – is a place in West Bengal, India, where great Indian poet Rabindranath Tagore, the first Nobel Laureate from Asia, founded in 1921 a university called Visva-Bharati. Abhoring his distasteful experience with schooling that taught regimentation rather than openness, Tagore wanted to "tie into the tradition of the Ashram – a spiritual and cultural center where students were educated outdoors" [Larsson, 2002]. The university embraced music, dance, and art, as well as language instructions and modern science, as part of its holistic curriculum. The university was intended to be a cultural centre for the whole of Asia, and reinforce common ties among all nations. Santiniketan became well-known to researchers and artists from around the world, the informal and open relationship between students and teachers making it attractive. Nobel Laureate economist Amartya Sen attended the school in Santiniketan as a boy. The messages of Santiniketan are its openness of communication, and learning outdoors with nature.

"Copenhagen Spirit" – *Der Kopenhagener Geist* – coined by Heisenberg – became an expression of the atmosphere that prevailed in the circle around Neils Bohr. He had the unusual ability to encourage ideas in others, and spot young talents with promise. Scientists visited Bohr to discuss with him and experience the milieu in which he worked, and were "infected with the feeling that they had participated in something great…" Bohr loved to converse with other physicists, engaging in prolonged discussions. The atmosphere in his institute was intimate and "unusually informal for the time – nothing else mattered except the ability to think clearly" [Larsson, 2002].

This provides a brief exploration of but three institutions that aimed at nurturing scientific and artistic creativity. There are many others; we need to identify and analyse them, look for the messages they live to pass on, and distil what can be learnt from them. Even though these were established at different era and matured over different durations, the message is remarkably similar – bring the best, varied minds, and provide an atmosphere that allows them to interact in the most open, unobtrusive manner. I wonder what messages are waiting to be discovered from the varied cultures of design creativity as we explore their souls.

3.3 Creative Individuals

We looked into five very different individuals. Each has proved his creativity in some area (all are Nobel Laureates), and came from a variety of disciplines.

Arne Tiselius, a Nobel laureate in chemistry in 1948, created new and hitherto unknown combinations from several known phenomena [Larsson, 2002]. This involved transferring ideas from many disciplines. From his mentor Theodore Svedberg, Tiselius grew an interest in the study of large compound molecules using physical methods, e.g. how various materials move through a solution under the influence of an electric current. Since different proteins move through electric fields at different speeds, such methods could be used to differentiate between these, enabling analysis of compositions of different biological samples – a process known as electrophoresis. Tiselius also developed instruments – a tradition influenced by his mentor Svedberg who made many discoveries using new instruments he developed. Tiselius believed that bringing researchers from various disciplines and encouraging them to "brainstorm' together, would enable cross-pollination of ideas.

Our second individual is Erwin Schroedinger – a Nobel laureate in Physics in 1933. A number of physicists including Schroedinger were dissatisfied by Bohr's atomic model which in their view was incomplete. While originally searching for a more comprehensive theory to explain quantum effects, Schroedinger did not persevere long after becoming a professor at Zuerich, with teaching and administration taking most of his time, until he came across the PhD work of Louis de Broglie in 1925 who proposed that quantum phenomena might be traceable to wave motion associated with the electron paths in an atom. Schroedinger sprang into action, and during the 1925 Christmas vacation, could formulate an initial version of his theory of wave mechanics [Larsson, 2002].

Rabindranath Tagore used a simple slate as a tool for releasing his creative powers. He spoke of the great relief he felt as he began to write on a slate instead of in a manuscript book. "While the manuscript book demanded him to fill it with something valuable, the slate freed him from these demands, as everything could be erased in one stroke" [Larsson, 2002]. He felt that the poetic style forced upon him limited his creativity. He had to spend time alone to get out of his rut. In one morning after such silence, for instance, inspiration gushed out, as in a religious experience, giving birth to his poem – Nirjharer Swapnabhanga (The Fountain's Awakening) [Larsson, 2002].

Playful curiosity characterised Richard Feynman's work. When he returned to academia after World War II, in spite of hard work, he could make little progress in his research,. As he analysed successes of his past, he realised that his playful attitude towards work were the driving force of his research. Once he went back to this, his research began to show successes, finally leading to a Nobel Prize in physics [Larsson, 2002].

The last individual we look into is Yusunari Kawabata – Nobel laureate in literature in 1968. As described in [Larsson, 2002], Kawabata favoured an "austere esthetic". The major themes of his work are love, death, loneliness and beauty. As a youth, Kawabata wanted to be a painter, but also had an intense interest in literature awakened early on, as evidenced from a journal he kept. The contents of the journal capture his feelings of sorrow and loneliness that marked his childhood – from his loss of parents when he was a few days old and his growing up in an isolated farm with his maternal grandparents. As put in by Larsson [2002]: a "melancholy mood came to characterize his future production."

What can we learn about creative motivation from these experiences? One is the influence of *teachers* in motivating and developing particular skills, as with Tiselius. Another is the *belief* of the researcher: that bringing researchers from multiple disciplines and brainstorming is good for creativity. Yet another is the role that being in contact with others' work plays, and the importance of a *prepared mind* to act upon it – as it was for Schroedinger. Yet another is the role played by the *medium* of work – as slate was to Tagore. Yet another is the importance of *being with oneself* – "relief from demands" – that gives time for incubation. *Playful curiosity* – as Feynman puts it, is another motivation for creativity. We also see the influence of *childhood* – as in the case of Kawabata – how the growing up influenced the mood of his creative work.

4 Conclusions as Beginnings

Taking ability, effort and opportunity as three major drivers of creative success, and taking knowledge (of domain and process, described in our earlier work as knowledge and flexibility respectively) and motivation (for developing and actualising knowledge), we propose here that research into design creativity should investigate the nature of knowledge, motivation and their synergistic interactions. We also argue that knowledge and motivation are capable of inflencing primarily ability and effort; opportunity remains largely beyond its scope. We then propose motivation and its influences on creativity as a major direction for design creativity research, and suggest three research approaches: exploring creative lineages, milieus and individuals. Using scientific creativity as an example, we explored one creative lineage, three milieus, and four individuals, with the aim of demonstrating that interesting insights could be obtained from taking on these approaches. These are but a few instances, but still provide interesting insights, and indicate that exploration of a larger group of cases – especially in design creativity, could produce a larger and stable set of insights into motivations for design creativity.

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