JIM
Journal of Innovation Management
The International Journal on Multidisciplinary Approaches on Innovation
Volume 5 Issue 3 | open-jim.org

ISSN 2183-0606
FEUP Edições

Journal of Innovation Management
JIM 5, 3 (2017) i-v
HANDLE: http://hdl.handle.net/10216/107952

Table of Contents

Editorial

Letters

Articles

ISSN 2183-0606
http://www.open-jim.org

Editorial Board Members (Economic and Social Science Areas)

Journal of Innovation Management
JIM 5, 3 (2017) 1-5
HANDLE: http://hdl.handle.net/10216/107952

Editorial

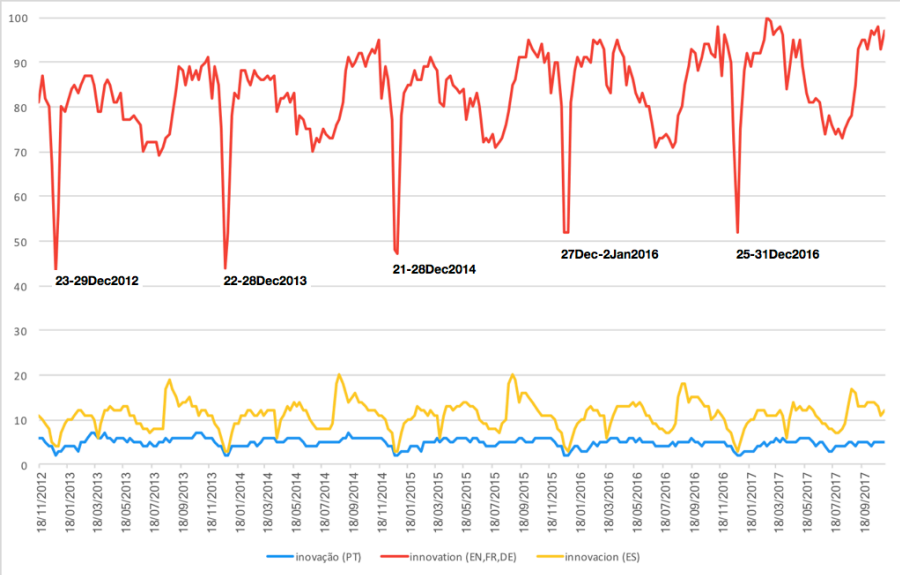
Is Innovation Interest Cyclical?

João José Pinto Ferreira[1], Anne-Laure Mention[2], Marko Torkkeli[3]

[1]INESC TEC - INESC Technology and Science and FEUP - Faculty of Engineering, University of Porto, Portugal; [2]RMIT University, Australia; [3]Lappeenranta University of Technology, Finland;

jjpf@fe.up.pt, anne-laure.mention@rmit.edu.au, marko.torkkeli@lut.fi

In the last issue of 2015, the editorial was titled "Winter is coming: The dawn of Innovation?" As almost 2 years have gone by, this topic was revisited. So why not wonder how *innovation was going around this same time of the year*? In trying to answer this question, a visit to Google© Trends revealed an interesting and possibly unexpected chart that is illustrated in figure 1.



An improvement to the Data Collection System was applied from 01/01/16 (for all charts)

In bold, inserted in the picture, the date periods corresponding to the lowest points on the chart.

Fig. 1. World interest along the time. *Innovation (EN, FR, DE), Innovacion (ES) and Inovação (PT)* as a search term in https://trends.google.com for the last five years. 100% translates a peak of popularity[1].

[1] Extracted from Google Trends explaining the contents of these charts: « *The numbers represent the search interest relative to the highest point of the chart for a*

ISSN 2183-0606
http://www.open-jim.org

The world coverage for the chart in figure 1 is pictured in figure 2 where we can see that some regions covered by the search.

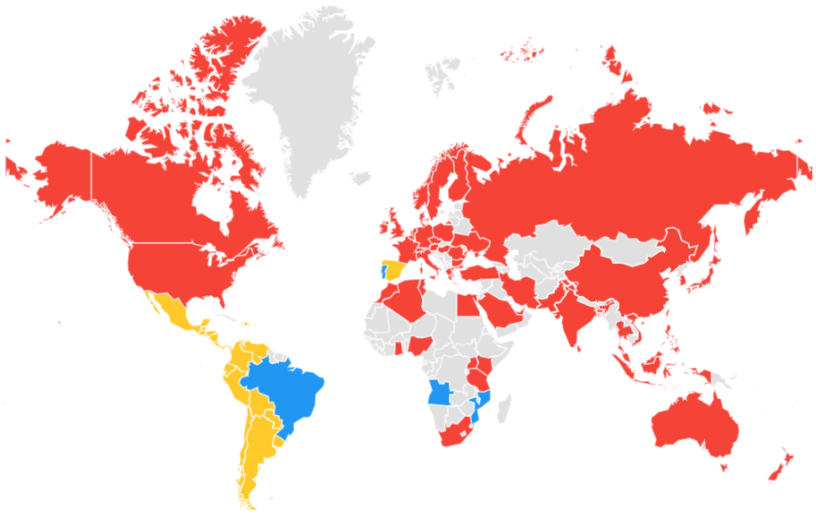


Fig. 2. Interest by region. *Innovation (EN, FR, DE) - Red, Innovacion (ES) – Yellow and Inovação (PT) – Blue* as a search terms in https://trends.google.com for the last five years.

Interestingly, this behavior looks very much periodic for these languages, with the lower point of popularity happening in the very few last days of each year or in the first days of the new year. These languages were selected as the four languages known by the authors listed in the report Languages for the Future – Which languages the UK needs most and why (2013).

A further detail from the search in figure 1, revealed that, for the English language, the users that looked-up the term *Innovation*, *also searched for (top five out of 25)*:

technology innovation	100
business innovation	100
innovation center	95
management innovation	70
new innovation	70

where 100 means the most searched term and 50 means that the term was searched only 50% of the times.

The periodicity discovered in figure 1 led to a new search, this time only in English, with the words *Innovation Management*. Figure 3 pictures the results, again for the last 5 years, and a somehow periodic behavior may be observed as well.

---

region and the specified time interval. A value of 100 is the term's popularity peak. A value of 50 means the term has half the popularity. Likewise, an assessment of 0 means that the term had less than 1% of the popularity relative to the highest point. »

Fig. 3. World Interest along the time. *Innovation Management* as a search term in https://trends.google.com for the last five years. 100% translates a peak of popularity.

In face of this, one may wonder, is this happening for all keywords? A new test with the keyword *Management* revealed Figure 4. Again, we can see some periodicity but with smaller peaks, more stable, but with lower popularity happening again in the last few days of each year. Another search was performed using the word *User Innovation* and the results are illustrated in figure 5, which seem to reveal no particular periodic pattern as observed before.

Fig. 4. World Interest along the time. *Management* as a search term in https://trends.google.com for the last five years. 100% translates a peak of popularity.

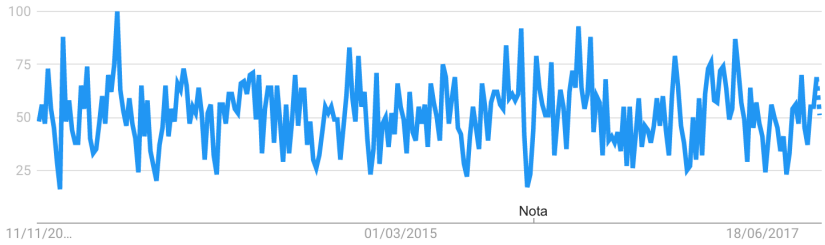


Fig. 5. World Interest along the time. *User Innovation* as a search term in https://trends.google.com for the last five years. 100% translates a peak of popularity.

It would be interesting to have an explanation for the observed behavior! One may wonder if a stronger popularity for the term *Innovation* just before the end of the year is related with companies preparing investments in innovation for the new year? Roughly, it is observed that the level of popularity starts going up from 75% by the end of August, then decreases just the days before the end of the year, and resumes in the new year to a similar level. This could be related to early stages of the project

implementation in the new year, decreasing again (until June), possibly as those projects get to a more stable stage of development. For *Innovation Management* one may observe as well an increase and a decrease, similarly as seasonal as for *Innovation*.

But is there any value in exploring innovation through "web interest"? Shaughnessy and Vitalari (2011) picture quite an interesting analysis where, by looking into "the US-specific data, we can also see that the more future oriented term *Open Innovation* and the current in-vogue term *Design Thinking* are beginning to close on the very tools-based term *TRIZ* in the United States." Figure 6 illustrates how the chart introduced by those authors now unfolds for the US-Region, but now for the last four years. In 2011 these authors further said that "Over the last few years, we found interest in TRIZ is losing ground to the less formal open and design paradigms" and this seems to be confirmed by the increase of interest in *Design Thinking*. Again, we can picture the periodic behavior modulating this increasing interest trend. However, this behavior was not observed in Shaughnessy and Vitalari (2011).

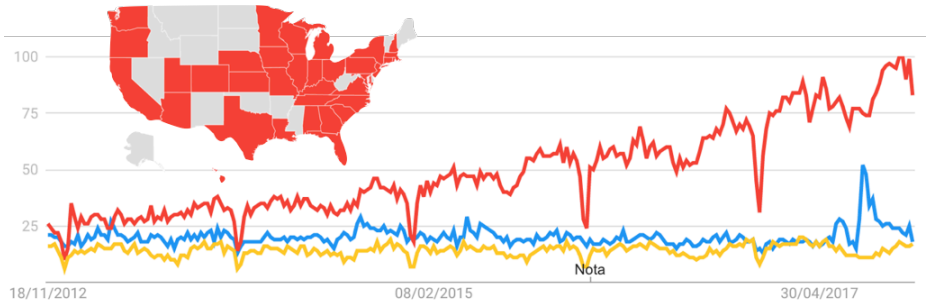


Fig. 6. World Interest along the time. TRIZ (blue) vs. Design Thinking (red) and Open Innovation (yellow) as a search terms in https://trends.google.com for the last five years. 100% translates a peak of popularity.

At this stage one would reasonably ask if there any research published specifically on the topic of innovation?

- A search in Scopus using *(KEY (google AND trends) AND KEY (innovation))*, reveals one paper, not directly related to the topic under discussion.
- A search in Scopus using (KEY (web AND interest) AND KEY (google AND trends)) revealed 4 papers, published in 2012, 2014, 2015 and 2017, with the following Author Keywords: *Algal blooms; Biodiversity; Climate change; Data mining; Google Trends; Individual interest; Interest; Public opinion; Public perception and interest; Social Issue forecasting; Social media; Social network service; Social Networking Sites; Twitter; Web search trends; Web Trends Forecasting*.
- A search in Scopus using (KEY (google AND trends) AND KEY (behaviour OR behavior)) revealed 35 papers. The analysis of author keywords in these 35 papers reveals 127 different keywords, and most of them with just one occurrence, only 10% had 2 or more occurrences.

It seems that researchers from many different areas are exploiting the potential of these tools for their own topics of interest. We would argue that these tools will become increasingly popular in order to analyze web interest / trends and will likely be used to decision makers. As an example, it could be cited (Kristoufek, L., Moat, H. S., et al. 2016) stating that "(…) a greater number of searches for the term 'depression' is related to fewer suicides, whereas a greater number of searches for the term 'suicide' is related to more suicides", and further arguing that results reported in that paper show the "potential value of online communication data for creating new proxy measures of psychiatric illness across large populations". Although not strictly related to the study of innovation, this illustrates how exploring large populations through "web interest" may bring new perspectives into the system under observation. So what is Yours Web Interest!

Innovatively Yours,

João José Pinto Ferreira, Anne-Laure Mention, Marko Torkkeli

Editors

References

Kristoufek, L., Moat, H. S., & Preis, T. (2016). Estimating suicide occurrence statistics using Google Trends. *EPJ data science*, 5(1), 32. DOI: https://doi.org/10.1140/epjds/s13688-016-0094-0

Languages for the Future – Which languages the UK needs most and why (2013) British Council, ISBN 978-0-86355-722-4

Shaughnessy H., Vitalari, N. (2011) The Global Innovation Interest Index. *Harvard Business Review*. Accessed October 2017. https://hbr.org/2011/06/the-global-innovation-interest

Journal of Innovation Management
JIM 5, 3 (2017) 6-13
HANDLE: http://hdl.handle.net/10216/107952

Leveraging robo-advisors to fill the gap within the SRI marketplace

Dimitrios Salampasis

Lecturer of Entrepreneurship and Innovation, Swinburne Business School, Faculty of Business and Law, Swinburne University of Technology, Australia

dsalampasis@swin.edu.au

Letter from Academia

The Socially Responsible Investing (SRI) marketplace has been experiencing continuous growth, despite the limited understanding and comprehensive tools for assessment, reporting, measurement and profiling of the investment portfolios, the risk and the generated impact. The materialization of robo-advisors, a new offering within the fund management industry, in the light of continuous technological developments, brings a new wave of innovation that aims at assisting the industry towards institutionalizing SRI strategies for the purpose of social good.

Keywords. SRI, Investment Strategies, Robo-Advisors, Artificial Intelligence, Fund Managers, Impact, ESG.

1 Introduction

In 1987, a TV series called Star Trek and the new generation of Starfleet officers on board the starship Enterprise, having the mission of travelling where no one had gone before, brought a different perspective in TV science fiction shows and space exploration. Among the crew of the Enterprise was Lt. Commander Data, an artificial life form officer, who looked exactly like a human being, always trying to imitate and sometimes endeavoring to capture the feelings and mysteries of the human nature. However, Data was a machine, who was able to conduct series of multiple and high complex algorithmic calculations, while providing advice to the rest of the crew on critical matters, based on rational calculations, historical data and formulas. 30 years have passed since the broadcast of the 1st episode of Star Trek and the introduction to our lives of the concept of an artificial life form. At that time this was still considered an element within the sphere of science fiction, however, 30 years later, robo-advisors are gradually becoming a real part of our lives, in different forms and contexts…

The aim of this brief letter, anchored in the ongoing disruptive developments across the FinTech landscape, is to provide some insights, on the emerging role of robo-advisors within the Sustainable, Responsible and Impact Investing (hereinafter SRI) terrain and interrelated opportunities challenges this entails for the fund/wealth management industry.

ISSN 2183-0606
http://www.open-jim.org

2 Sustainable, Responsible and Impact Investing Strategies

SRI stills remains an elusive and multidimensional notion capturing many interconnected, interrelated and difficult to understand elements that exist individually, but neither necessarily interdependently nor constantly. This multidimensionality has been extensively explored but there is still no broad consensus around a conceptual framework that captures the various and different dimensions of Sustainable, Responsible and Impact Investing.

The core of SRI is grounded into the co-existence of investors' financial objectives and their concerns about Environmental, Social and Governance (ESG) issues within an investment process. SRI is branched into responsible, sustainable and impact investing. Each of these three pillars incorporates a number of investment strategies, which can be complementary and can be deployed in various (and often blended ways) ways by the investor in the process of incorporating ESG criteria.

The broader area of responsible investing has been experiencing an increased growth, along with, raising of awareness, within the past decade. US-domiciled AuM adopting SRI strategies increased to $8.72 trillion within 2016, an increase of 33% since 2014 (USSIF, 2016). Moreover, global sustainable investment assets reached approx. $22.9 trillion AuM, experiencing a 25.2% increase since 2014 (GSIA, 2016). Furthermore, within the European landscape, SRI strategies remained within a growing trajectory, 'with rates between 14% and 57% CAGR for the main strategies, while Impact Investing-still the fastest growing strategy-is at 120% CAGR' (Eurosif, 2016, p.12). These numbers show indeed a marketplace with great potential and demand, also in the light of the recent developments in the Sustainable Development Goals (SDG) landscape and the continuous willingness from different cohorts of investors to align their investment objectives with their values and the generation of positive social and/or environmental impact. However, this has not always been the case since primarily, in this context, investing has been associated the notion of responsibility (exclusionary process) substantially diminishing the investable area and leading to a potential negative investment performance, by either increasing risk and/or reducing returns. In addition, responsible investing and the societal element that it entails has been for long considered as a taboo, since it was contradictory to the prevailing narrative that the asset manager's fiduciary duty is all about financial return maximization.

Within the last couple of years, the incorporation of ESG criteria (which in many cases was conducted in a non-systematic and unstructured way) has moved beyond the traditional negative screening process (which is primarily based on ethical and/or norm-based considerations) to a more active and positive approach i.e. focusing on companies that depict a positive score on ESG factors, but also show tangible progress in the way they score on ESG factors.

One of the foundational and most important elements within the responsible investing landscape is the practical integration of ESG considerations into the process of investment decision-making (pre-investment diligence but also post-investment monitoring) [USSIF, 2015]. In simple terms, ESG integration goes beyond the analysis and assessment of corporate financial data. It provides additional valuable content by including into the analysis intangible factors related to environmental, social and governance issues. ESG integration is defined as "the explicit inclusion by asset

managers of ESG risks and opportunities into traditional financial analysis and investment decisions based on a systematic process and appropriate research sources" (Eurosif, 2014, p.17)). ESG integration brings on board a proactive approach in terms of managing the investment process across various asset classes, traditional financial performance metrics and practices of managing risk (Zurich Insurance, 2014). It is important to clarify that even though positive and negative screening tactics are by default embedded within ESG factors, ESG integration brings an alternative way of looking into the ESG analysis that goes beyond the standalone screening approaches (NEPC, 2015).

Looking beyond the monolithic way of acting responsibly, the integration of ESG criteria within the investment decision-making process brings a consolidated approach in the investment strategy since it emanates sustainability; the overall aim of this kind of investment strategy is about investing in sustainable and innovative business models that in the long-run can lead to positive investment performance. In this context, a number of studies has shown that the incorporation of ESG factors within the assessment of the investing portfolio can have a positive impact on the investment performance and failure or ommitance to include can lead to incomplete or even incorrect investment decision-making (Eccles, and Serafeim, 2013; Isaksson, and Woodside, 2016; van Duuren *et al*., 2016).

3 Positive impact on global challenges

Governments have, for long, been considered as a monopoly when it comes to dealing with social and/or environmental issues; however, their role in terms of providing answers to diversified societal needs has been disappointing in the eyes of people interested in social issues. In this frame of reference, the impact investing paradigm, which gradually gains momentum in the marketplace, channels innovation, entrepreneurship and capital to empower social progress, allowing for an alternative mindset towards investments.

Impact investing, as an investment management strategy across asset classes, brings an entire different logic within the responsible investing landscape, which, at the same time, creates a number of crucial challenges requiring immediate attention. In fact, the primary challenge originates from the very multidisciplinary nature of impact investing.

What makes impact investing unique is the dynamic co-existence of generation and demonstration of intentional (and unintentional) impact, both in a clear and attributable manner. By definition impact investing is the active placement of intentional capital (incl. non-monetary activities) to enterprises with the purpose of generating social and/or environmental impact (ultimate social outcome), along with, expectations of financial return and consideration of risk. According to these existing narratives and definitional considerations, impact investing is projected in a three-dimensional spectrum: impact, risk and return, with each of these pillars h0lding a fundamental role in the impact investing landscape.

One of the foggiest and highly debatable aspects of impact investing is related to the understanding, the measurement and the reporting of the perceived and generated

impact and calculation of social good. Measurement of social impact is considered as a paramount enabler in the process of achieving financial and social returns, since it really identifies and scales what actually makes sense and works in alignment with social objectives (intentional and unintentional). It is a tool that enables access to capital and opens door to innovation by allowing investors perceive a social and philanthropic pathway.

However, the high-quality measurement of social impact, along with, the reporting mechanisms are considered as the dark side of impact investing. This fact is primarily grounded on the limited development and adoption of concrete impact indicators, tools and processes for assessing development (social) impact and financial performance. Needless to say, that, this measurement and reporting deficit, along with, often observed lack of transparency, additionallity, honesty and accountability, hinder the credibility of impact investing, especially, in the eyes of tax-payers who are expecting the generation of tangible social impact. Furthermore, it creates strong ambiguity in the eyes of investors. In this frame of reference, this discussion is cutting-edge since it is all about connecting the measurement of social impact with capital markets in order to create a powerful force to improve the lives of others within underserved markets.

A number of industry-sponsored organizations have put together sophisticated and often "competing" measurement frameworks, indicators, reporting metrics and platforms (e.g. IRIS, PULSE and GIIRS). Still, a common language around impact measurement is missing and not a widely accepted definition of social value exists so far. This reality is also reflected in the inherent difficulty to integrate concise reporting procedures. Consumers, investors and donors are constantly inquiring for a magnitude of information. This becomes crucial for organizations to be able to provide such kind of information in a meticulous, rigorous and trustworthy manner, contributing to their reputation and leadership within their respective markets.

This nascent investment area is still in its infancy and endeavors towards developing more standardized approaches, which are of relevance for different sectors, move at a glacial pace. Furthermore, time and cost are considered as key barriers when it comes to integrating impact measurement methods and tools in the investment and decision-making process, both in the pre-investment due diligence, the pre-approval and the post-investment monitoring phases.

So and Staskevicius (2015) propose five key measurement objectives, which can be integrated into the investment cycle:

- **Estimating impact**: this objective corresponds to the pre-investment due diligence phase. During this phase impact investing organizations determine the impact that the potential investment may create, allowing the investors to prioritize the allocation of resources in such a way that can create the intended impact;
- **Planning impact**: this objective corresponds to the pre-approval phase. During this phase impact investing organizations enter into a negation and/or shortly-post investment cycle, developing all the necessary tools and methodologies to plan the impact measurement;

- **Monitoring impact**: this objective is part of the post-investment monitoring phase. In this part of the phase progress is monitored by the reporting of data, information, financial elements etc. This objective may also serve the purpose of re-organizing and re-visiting part of the project and investment portfolio in order to apply "corrective interventions";
- **Evaluating impact**: The use of the word "evaluation" hereby allows for the unveiling of insights in relation to context, strategy, organizational, human and system capabilities, elements that cannot be measured with traditional means. Evaluation brings together a broader perspective into the understanding of impact moving beyond the measurement narrative;
- **Reporting impact**: This objective is all about external communication of the project/investment outcomes to the beneficiaries.

Brest and Born (2013), introduce three basic parameters of impact:

- **Enterprise impact**: "the social value of the goods, services, or other benefits provided by the investee enterprise"
- **Investment impact**: "a particular investor's financial contribution to the social value created by an enterprise" and
- **Non-monetary impact**: "reflects the various contributions, besides dollars, that investors, fund managers, and others may make to the enterprise's social value"

The biggest question when it comes to impact investing measurement is to determine if the investment actually has an impact. It is also important to understand and decide on what can and cannot be measured, because even though many things have a social return it does not mean they can generate a financial return. Funds that some may consider to be inherently impactful based solely on the investment portfolio cannot be considered as impact investing. The key determinant is the intent of the fund manager. Being an investor in an impact theme sector does not automatically grant an impact investor status; fund managers must be able to demonstrate their intentionality in terms of creating positive impacts as part of their core strategy. Moreover, funds, which only seek to encourage an ESG-minded philosophy within their portfolio companies cannot be put in the impact investing landscape. Naturally, these kind of policies may certainly generate societal benefits, but this is not an adequate indicator for social impact generation.

The measurement of social impact needs also to take into consideration the factor of time and the element of counterfactual. However, social problems are intractable and they cannot be solved overnight. But, this does not mean that positive outcomes are not created. To that respect, fund managers need to look for correlation rather than direct causality in their process of understanding and developing the investment strategies. They also need to see the collective impact generated via the collaboration of different impact investors both on tackling community-based projects and on the sector, which can have create a paradigm shift, beyond the particular mission.

Despite the growth and integration of ESG factors there are still a number of challenges and gaps, which need to be addressed: a) the application and disclosure of ESG criteria and the systematic and consistent ESG integration across asset classes. The existence of specialized ESG advisors possessing strong technical skills but also the ability to

embrace alternative investment approaches and understand intangible and non-financial parameters, the clarification and standardization on labelling and the institutionalization of education and training programmes in order to build awareness and skills will help the responsible investment landscape become a truly mainstream market.

4 Robo-advisors making SRI in demand

The emergence of technological breakthroughs leading to new applications of Artificial Intelligence and Machine Learning, could not have left the SRI marketplace unattended. A number of 'socially conscious' robo or digital (automated) investment advisor platforms incl. Betterment, Wealthfront, Motif, Earthfolio, OpenInvest, M1 Finance, Passed Pawn Advisors, Hedgeable, Prophecy, Stash, TIAA Personal Portfolio, Wealthsimple, Swell and Grow Invest have emerged within a competitive SRI marketplace providing different values-based investing tools and investment portfolios built around SRI investing strategies, allowing socially conscious investors to tailor their own investment portfolio mix around socially conscious funds, assets or companies based upon their risk tolerance, investment objectives, values and in alignment with ESG criteria (incl. positive ESG performance indicators) and generation of a positive impact on the world. These online investment platforms either use algorithmic calculations or 'rules-based' investment approaches.

The increasing demand from investors (incl. millennials, Gen X, Baby Boomers) for blended investment portfolios that amplify their personal values while having the ability to generate positive financial returns, along with, the complexities of these investment portfolios and the limited institutional investing expertise, have provided room to automated investment advisor platforms to gain a considerable part of the SRI marketplace. Investing in innovative solutions to address numerous global challenges and the aspiration of accelerating long-lasting, sustainable social and/or environmental impact, within public and private markets, is one of the main reasons why investors are keen on exploring digital investment advisor platforms. In this context, the unique value proposition of such kind of platforms is related to the opportunity they provide to different cohorts of investors to experiment with different investing vehicles and tools emanating the symbiotic relationship between the market and society logic.

Based on the abovementioned analysis, the SRI landscape is characterized by a diverse 'multilingualism', which creates more confusion than understanding of the different and diverse tools that are available in the market; needless to say that primarily these human advisory options come with a substantial cost for the investor. The urge to incorporate ESG principles, along with, the ultimate willingness to craft investment portfolios that reflect personal norms and values tends to be the unique value proposition of these emerging automated platforms. However, the fundamental question remains: how is it possible for a robo-advisor to be able match personal and ethical values with investment portfolios? In other words, how can an automated investment advisor be able to capture the essence of responsibility, sustainability and impact based on algorithmic calculations and historical data, particularly when the current marketplace is so fragmented in terms of a comprehensive understanding of what the SRI landscape should look like?

4 Concluding remarks

The fund management industry is definitely affected by all the applications emerging from various technological breakthroughs. Innovation is required both from a process point of view and an outcome point of view; innovation that would allow the generation of investing tools and vehicles that aim at providing pathways and funding mechanisms to novel business models that tackle pressing global challenges and wicked problems. The mental framework and state of mind of a new cohort of socially-conscious investors that is currently coming on the scene requires alternative functional, advisory and executional capabilities on behalf of investment advisors, along with, the ability to synthesize multiple parameters, factors and insights (financially and non-financially driven) that can lead to optimal outcomes. The evolution of 'hybrid' forms of advisory (combinative forces of human and AI capabilities) is expected to pave the way towards a comprehensive reconceptualization (learning, unlearning and relearning) of the SRI marketplace and democratize these types of investments for a good cause.

5 References

Brest, P., & Born, K. (2013). When can impact investing create real impact? *Stanford Social Innovation Review*. Accessed 15th November 2017. http://ssir.org/articles/entry/unpacking_the_impact_in_impact_investing

Eccles, R.G. and Serafeim, G. (2013). The performance frontier. Harvard Business Review, 91(5), pp.50-60.

Eurosif (2016). 'European SRI Study 2016'. Accessed 15th November 2017. http://www.eurosif.org/wp-content/uploads/2017/11/SRI-study-2016-LR-.pdf

Eurosif (2014). 'European SRI Study 2014'. Available online at http://www.eurosif.org/wp-content/uploads/2014/09/Eurosif-SRI-Study-20142.pdf

GSIA (2016). 'Global Sustainable Investment Review 2016'. Accessed 15th November 2017. http://www.gsi-alliance.org/wp-content/uploads/2017/03/GSIR_Review2016.F.pdf

Isaksson, L.E. and Woodside, A.G. 2016. Capturing complexity in how configurations of firm Internal Orientations impact corporate social performance outcomes: Breaking from the dominant logic of symmetric-variable to asymmetric-case-based theory and testing. Australasian Marketing Journal, 24(4), pp.300-308

NEPC (2015). 'Completing the Analysis: ESG Integration'. Accessed 15th November 2017. https://cdn2.hubspot.net/hubfs/2529352/Blog/2015_11_nepc_completing_the_analysis-_esg_integration.pdf?t=1486746354842

So, I., & Staskevicius, A. (2015). Measuring the impact of impact investing. Harvard Business School. Accessed 15th November 2017. http://www.hbs.edu/socialenterprise/Documents/MeasuringImpact.pdf

USSIF (2016). 'Report on US Sustainable, Responsible and Impact Investing Trends'. Accessed 15th November 2017. http://www.ussif.org/trends

USSIF (2015). 'Unblocking ESG Integration'. Accessed 15th November 2017.
http://www.ussif.org/files/Publications/UnlockingESGIntegration.pdf

van Duuren, E., Plantinga, A. and Scholtens, B. (2016). ESG integration and the investment management process: fundamental investing reinvented. Journal of Business Ethics, 138(3), pp.525-533

Zurich Insurance (2014). 'Responsible Investment in Zurich'

JIM 5, 3 (2017) 14-33
HANDLE: http://hdl.handle.net/10216/107952

Emergence of Digital Twins - Is this the march of reason?

Shoumen Palit Austin Datta

Senior Member, MIT Auto-ID Labs
Research Affiliate, Department of Mechanical Engineering
Massachusetts Institute of Technology, Room 35-203, 77 Massachusetts Ave Cambridge, MA 02139, USA
Senior Scientist, Medical Interoperability Program, MDPnP Laboratory
Massachusetts General Hospital, Harvard Medical School
Partners MGH Research Building, 65 Landsdowne St, Cambridge, MA 02139, USA
Managing Director, NSF Center for Robots and Sensors for Human Well-Being
School of Engineering Technology, Purdue Polytechnic, Purdue University
156 Knoy Hall, West Lafayette, IN 47907, USA
shoumen@mit.edu, sdatta8@mgh.harvard.edu

Letter from Academia

Multiple forms of digital transformation are imminent. Digital Twins represent one concept, where we may use tools and technologies to "map" data (bits) from objects (atoms). It is gaining momentum because the "map" can act as a "compass" to reveal the status of atoms (things, devices, components, machines, people), process visibility and real-time transparency. Adoption of digital proxies, or digital duplicates, may face hurdles due to lack of semantic interoperability between architectures, standards and ontologies. The technologies necessary for automated discovery are in short supply. Progress depends on the convergence of information technology, operational technology and protocol-agnostic telecommunications. Making sense of the data, ability to curate data, and perform data analytics, at the edge (or mist, rather than in the fog or cloud) is key to value. Delivering algorithm engines to the edge, are crucial for edge analytics, if latency is detrimental. The confluence of these, and other factors, may chart the future path for Digital Twins. The number of unknown unknowns, and the known unknowns, in this process, makes it imperative to create global infrastructures and organize groups, to pursue the development of fundamental building blocks. We need new ideas and research in new domains to generate creative and innovative solutions.

Keywords. Digital Economy, Digital Twins, IoT, Agents, AI, Analytics, Cognitive Firewall, Cognitive Compass

1 Introduction

Being Digital (Nicholas Negroponte, 1996)[1] and *When Things Start To Think* (Neil Gershenfeld, 2000) [2] introduced the public to the potential emergence and the rise of smart machines. About a decade later, Jeff Immelt of GE started to market these ideas

ISSN 2183-0606
http://www.open-jim.org

in the *minds and machines* campaign, claiming a future where self-organizing systems, sub-systems, multi-component subunits and modular embedded code, shall define the next generation of adaptive intelligent machines. When can we expect *that "next" generation* to emerge?

In 1513, the discovery of the isthmus at Panama by Vasco Núñez de Balboa triggered the idea of creating a trans-oceanic canal. Francisco Lopez de Gomara suggested (in his book, in 1552) Panama, Nicaragua, Darien and Tehuantepec as choices for a canal. Not for another 300 years, not until the 19th century, would the canal building actually commence under the leadership of Ferdinand Marie Vicomte de Lesseps a French diplomat. Ferdinand de Lesseps (19 Nov 1805 to 7 Dec 1894) could not complete the Panama Canal and did not live to see the successful completion of the Panama Canal in 1914 by the US Army Corps of Engineers[3].

Creating intelligent adaptive machines faces a similar uphill battle. Our optimism is not unfounded but it may be burdened by the dead weight of old technology. Paving the path for new theories, new concepts and new forms of connectivity, in engineering design, of future systems, may lead to intelligent (?) machines. A greater challenge may be introducing cognition in systems, due to our wobbly and poor understanding of what constitutes intelligence[4] (AI).

Companies, afraid to delve deeper, are retrofitting existing machines with sensors to designate them as *connected*. Attaching sensors supposedly makes them *smart*. Workflow on steroids is peddled as *intelligence* in analytics. Others are collecting and feeding big (noisy) data sets to existing software systems and claiming "cognitive software" in use. The tapestry of buzz words and patch-work of programs are introducing glaring gaps, generating errors, callous disregard for physical safety, and inept approach to cybersecurity[5] in general.

One reason for the confusion, perhaps, is our general inability to ask correct questions. These are some of the questions from the field. What machines, devices and systems may be built with the tools and technologies at hand? How should we build and use them? Do we really want to just connect everything to collect big volume of data? Is it really all about data? What is data curation? How can we teach machines to achieve specific goals? Are these the correct questions to ask? *Are these the questions even worth answering?*

The debate rages on about answers. These and other related questions may find some answers hidden in bio-inspired design principles. Progress in bio-MEMS, bio-NEMS and molecular machines[6] coupled with biological mimicry and cybernetics[7] are elements which may (?) converge with AI[8] in an over-arching strategic[9] plan. Integrating that plan to inform engineering design is the Holy Grail. The command, control, and coordination of bio-inspired engineering design requires hardware-software synchronization, *by design* (not later).

Time-synchronized hardware-software integration is one hallmark of cyber-physical systems[10] (CPS) which is the foundation of embedded[11] systems. The concept of digital twins emerged from NASA. Time guarantee (concurrence) in embedded systems is critical for aero/astronautics. To advance the diffusion of the digital twin concept, we must adopt practices[12] borrowed from CPS[13].

The current advocacy to advance the principles and practice of digital twins, from

manufacturing to healthcare, calls for connectivity, by design. Systems should be able to *discover*, inherit, evaluate and share intelligence across sub-components and coordinate to turn on/off modular code embedded in sub-systems. We may monitor, analyze, control units (PLC) and sub-units, in real-time [14](sensors, actuation) and visualize operations not only at the system level, on-site, but attempt to view the operation of the entire ecosystem[15]. The latter, may accelerate diffusion of digital transformation using a systems engineering approach.

2 The Rationale for Digital Twins

2.1 Signal vs Noise – IoT vs Digital Transformation

The term IoT may have been coined at the MIT Auto ID Center (1999), but the past, present and future[16] concepts of IoT have been brewing for almost a century. Milestones include Isaac Asimov's "Sally" the fictional autonomous car[17], Herbert Simon's seminal paper[18] ("talk to the computer"), Hiroshi Ishii's idea of "Tangible Bits" (People, Bits and Atoms[19]), Mark Weiser's paper[20] "Activating Everyday Objects" as well as the 1991 article (Scientific American)[21] and the vision[22] of the "networked physical world" by Sanjay Sarma[23], David Brock and Kevin Ashton (2001). The IoT roadmap[24] promises to be even more dynamic in the future and scholarly discussions, including one by Alain Louchez[25] outlines the layers of influence, hence, the challenges ahead.

IoT is a digital-by-design metaphor and a paradigm for ubiquitous connectivity. The value proposition rests on proper use of plethora of tools and technologies that must converge to make sense of the data. The hypothetical transparency is of little use without the data of things, if we wish to profit from IoT applications. On the other hand, digital transformation is a cacophony of ideas open to innovation from wireless systems[26] as well as broadband communication[27] and forthcoming 5G for time critical[28] operations. The latter, if combined with 8K[29] visualization, may catalyze robotic surgery. Masses may benefit from standard surgical procedures such as laparoscopic cholecystectomy, appendicitis and phacoemulsification (cataract removal).

CNC machines, ERP, Web 2.0, fixed-task robots are examples of waves of digital transformation in business. The 2012 proposal[30] from Sanjay Sarma of MIT Auto ID Labs to pursue a **Cloud of Things** initiative resonated globally and the concept was promoted by others (Finland[31], France[32] and South Korea[33], to name a few). The next wave appears to be the transition from manufacturing products (items to be sold), to the creation of a service ecosystem, around the product, to sell service as a pay-per-use model. Digital transformation includes establishing a digital leash to monitor, promote, connect, track and trace, in order to monetize every point of contact in the relationship (digital CRM), not only once (sales of product), but over the life time of the customer. Hence, product lifecycle management evolves to digital PLM with quality of service (not product delivery) as the KPI, and monetization tool. Quality of service (QoS) emerges as the *readiness* metric to gauge customer satisfaction. If QoS metrics are maintained by provider(s) or manufacturer(s), then the client or customer is expected to pay for the QoS level associated with the product-service, per contractual agreement,

as long as the customer is consuming the benefit.

In instances where the product is not an object (eg, teleco) the business models are inextricably linked to "outcomes" the customer expects. Monetization of digital transformation from an outcome-based model is complex, due to the ecosystem of players and alliances. It is not easy to optimize and arrive at the point of convergence, to deliver the outcome as a seamless function, which involves end-to-end value chains, operating as a pre-agreed platform.

The task associated with monitoring each instance of engagement for micro-revenue collection and its disbursement is complex. We need to track each instance, and maintain a record of connectivity, in an irrefutable evidence log (eg blockchain[34]). The latter may act as a digital ledger[35] to validate fractional micro-payments, due from each point of contact (PoC). The digital id of the service, delivered at the PoC, identifies the member of the supply chain providing the unit of service, at that specific instance. The latter may be a part of the sum of services, in the portfolio, that defines the service, and each may be weighted by a QoS the customer expects. The customer pays for the final outcome (*value* in the value chain). The sum of the parts must be delivered *before* the value perishes. The duration of that value may be widely divergent (compare retail vegetables in a grocery store vs data to predict risk of diabetes).

Synthesis of the parts to act as a seamless function is the challenge. Who will build the parts of the platform, which will be sufficiently open, and interoperable, to connect with the innumerable end points, at the edge? Who will build the blocks for the digital modules? Who will build the blocks for the blockchains?

2.2 Digital Twins

Scenario

> *Schlumberger is monitoring a drill-head in operation, on a drilling platform, in Outer Hebrides to determine the MTBF (mean time between failure) metric, and trigger replacement, to prevent work stoppage on the rig.*
>
> *The camera at the tip of the drill-head, and drill-head (drill-case) sensors (eg, vibration, temperature, gyroscope, accelerometer) transmits (wired, wireless) video, audio and other data which must be analyzed as close to real-time as possible, with respect to object identification, precision geolocation and process linkage. AI (?) analytics updates MTBF metrics. Depending on MTBF range (80%, 90%) as decided by business logic (when to replace), the drill-head spare parts supply chain (service, fulfillment) must be connected to auto-trigger the "head" when the MTBF range is reached. Purchase orders [supplier(s)] are followed by transport and logistics for delivery, and workforce scheduling, to execute the replacement prior to breakage (payment, contracts, invoices, and accounts payable, must be connected). Data about the drill-head, and lag time for each process/operation is captured by the operations management team, at a remote location, for future aggregate studies or collective evaluations. Can we visualize this entire end-to-end process as a Digital Twin operating in real time?*

In our current *modus operandi* this operation involves a plethora of operational silos (OT, drilling operation, mechanical engineering, systems, supply chain, finance, human resources), software (connectivity between different locations, cloud infrastructure, cybersecurity) and hardware (not only the spare parts and drill-head but also the computational hardware/servers at different locations which are essential for IT infrastructure).

The concept of DIGITAL TWIN posits that the flow of data, process and decision (this hypothetical scenario) is captured in a software ***avatar*** [36] that mimics the operation or offers, at the least, a digital proxy.

The 3D "twin" or its digital proxy, may be visualized by an analyst or manager, on a location-agnostic mobile device (iPhone, iSkin). Drilling down on a schematic illustration with the word "drill-head" may link to the live video-feed from the drill-head camera which opens up on a new GUI (tab or window). Data fields (features, attributes, characteristics) related to the drill in operation (pressure, torque, depth, temperature, rotations) are visible by clicking on the icon for the drill. A plot showing the data, approaching the MTBF metric, may be instantiated using a command (icon "plot data"). It shows how the live sensor data is feeding the dynamic plot, displaying the characteristics of the drill-head, and the rate at which it is approaching the MTBF. The range may be set by humans (or the system), using prescriptive and/or predictive values based on "learned" values from machine learning tools operating in a "diagnostic" mode.

Will it allow for "what if" analysis? If the analyst viewing the Digital Twin, wishes to change the MTBF range and explore how the downstream processes may change (see principles of http://senseable.mit.edu/). The digital proxy for supply chain should spring into action, displaying delivery lag times from different suppliers, and cost of normal vs expedited delivery. The material composition of the alloy used in manufacturing the drill-head should be visible. The analyst may use an *ad hoc* selection process and identify a new vendor. Can the system trigger process workflow to alert the people (roles) along the way to clear the requisition, and generate purchase order for the new supplier? Can it auto-verify the new supplier to check credentials, inventory, cost, transportation scheduling, quality of service reports and customer reviews of prior contracts?

We are still on the mobile device or laptop with the Digital Twin app or its digital proxy. We watch the drill-head in action and a window displays the real-time data/analytics approaching MTBF. Using a different app, we identify a supplier to custom-design and 3D print-on-demand a drill-head with precision fit (think prosthetics). The supplier (www.quickparts.3dsystems.com/social-solutions/) downloads the video feed (from the cloud) of the drill-head operating in Outer Hebrides. The manager monitoring the end-to-end chain [a] selects the team of engineers who will replace the 3D printed drill using a HR menu which lists skill sets, proficiencies and years of expertise by category [b] pre-sets the command on the digital twin to actuate the replacement supply chain process, when MTBF reaches 72% because fulfilment takes 21 days, and by then (that is, 21 days later) the MTBF is predicted to reach 85% (code red – replace).

Each sub-unit provider must collaborate and synchronize (systems, standards, semantic interoperability) their role in the operation, and the *representation* of their function in

the digital proxy, or in the digital twin model, in near real-time. The plethora of system providers, suppliers, third party software, analytics, cloud storage, fog providers and hardware component manufacturers - **also** - expects to be paid for the outcome, desired by the company (customer).

The design of content, and connectivity between such vast system of systems, calls for new principles of model-based systems engineering, to integrate global standards, to anchor architectures[37] responsible to drive the digital by design paradigm. New models must inculcate the IoT digital-by-design metaphor with respect to connectivity by design, interoperability between standards by design, and cybersecurity by design. The silos of OT, IT and telecommunications must converge, to create this new digital-by-design foundation for digital proxy and/or digital twins (digital proxy plus 3D models). In this paradigm shift, objects and things may not be baptized *after* birth to follow the digital persuasion, but will be born free of analog baggage. It may not need a path to digital transformation because they will be *born digital*.

Configuring Digital Twins: Creating the Blocks – Blockchain Paradigm? Lessons from cyber-physical systems (CPS) with respect to operational time synchronization may be key for certain forms of architecture for digital twins. Without open repositories, the process of creating (building) digital twins and the adoption of digital twins may be restricted to an industrial oligopoly. The vast majority of users cannot deploy an army of engineers to create custom digital twins for their exclusive experiments.

Rapid diffusion of digital twins calls for open source entity level models of sub-components (units). Think of each SKU listed in a BOM (bill of materials), as a system made up of sub-systems. Next, imagine each sub-system with unit parts to serve as the "block" or base level unit which needs to be created (built). The "old world" notion may have stopped at the physical manifestation - the actual unit made of tangible material. In a digital twin world, we need a digital version.

In the era of digital twins, we will call on the *source*, that is, the CAD/CAM model owner of that unit, to create and *contribute* to a common repository (?) the software representation of the unit, replete with the physics of the material, and the engineering characteristics of its operational function. For example, the physics of the part will inherit natural laws which governs all entities. For example, if a spare part were to fall off a table (on this planet), it will fall ***down*** at a rate defined by the acceleration due to gravity of 9.8 m/s^2. The latter is an inherited[38] attribute from the laws of physics (characteristics which forms the base in a 'layer cake' model).

To the informed mind, it is clear, we have encountered and entered the domain of semantics and ontologies.

The digital twins of the granular units (parts), to be useful, must be connected by their relationships to the relevant data feeds from sensors/gateways. These entity relationship models and parts (connectivity) must be accessible to managers or analysts who can drag and drop the parts from the repositories on a "sense" table (device GUI). The ontology of entity level relationship models for digital twins may use bio-inspired principles. Elements[39] from disease models, for example, a bio-surveillance model, is shown below in Figure 1.

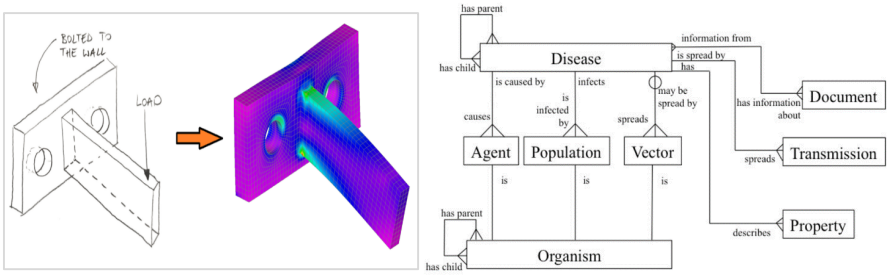


Fig. 1 - Digital twins as models of reality (illustration on left from [1] and right from [2])

To the untrained eye the cartoons may not suggest the cryptic complexity that must form their foundation. These foundations are "layer cakes" (for example, TCP/IP) which must be able to communicate with other "layer cakes" (for example, semantic web[40]) built on other principles, concepts or ontological frameworks. It is imperative we minimize the number of such architectures in order to fuel interoperability between architectures (requires interoperability between standards, access to open data dictionaries and shared ontologies).

The abstraction of the building blocks necessary for the digital twin movement may be similar, in principle, to the building blocks necessary to implement the use of blockchains, as a trusted digital ledger of connected instances. Who can we trust to build the blocks? This question is critical to practitioners of digital twins and blockchains. Both these concepts share homologies with IoT as a digital-by-design metaphor. The "block" in IoT may be the integrated platform, synthesized from subunits or blocks, containing data, of things.

The rate limiting step, which defines the functionality of all of the above, is inextricably linked with, and driven by the principles and practice of connectivity. In order to deliver value, connectivity must span a broad spectrum of dynamic ecosystems. Implementation of such connectivity must be protocol-agnostic, location agnostic and time sensitive (maximize transmission, minimize steps), with respect to "sense and response", between the edge and the core. Since IoT is expected to connect trillions of things, scalability will be a key enabler.

Have we encountered such "block" and "connectivity" concepts elsewhere? The common answer is Agent[41] systems. Marvin Minsky's *brain connections* related abstraction[42] **"cube on cube"** illustrates this concept where each cube is a software Agent. It is relevant to this topic because each cube may be viewed as a "block" in the blockchain or a baseline 'unit' in the digital twin paradigm (digital proxy of physical entity). The origin of the concept from software Agents, emphasizes the link to semantics, ontology, and related roots, which could go as deep as neural networks, cognition and even epistemology.

[1] https://enterfea.com/wp-content/uploads/2017/04/A0-4.png
[2] https://arxiv.org/ftp/arxiv/papers/1609/1609.05774.pdf

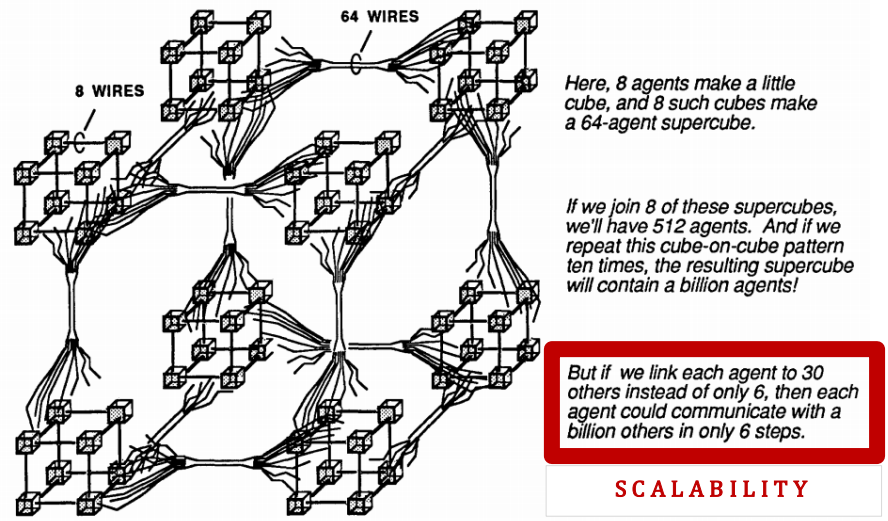


Fig. 2 - Illustration from page 315 (Appendix: Brain Connections) from *Society of Mind* by Marvin Minsky. MIT, 1985

The illustration (cube on cube) simplifies Minsky's abstraction and the principle of "blocks" to represent objects, data, process and decisions (outcomes). The blocks, when connected, can synthesize a variety of entities or networks[43] joined by common digital threads. Alignment of appropriate blocks can lead to creating platforms necessary for implementation of IoT. Parts and sub-units, can be configured, to create a digital twin of a machine (drill-head). Instances and units of transactions, represented as blocks may constitute a digital ledger of events, similar to application of financial transactions using blockchain.

For a scenario at hand, please consider the act of driving your automobile (if you can still use a gas guzzler with an internal combustion engine[44]) to the proximity of a gas dispenser stand in a gas station (petrol pump).

Your car recognizes "arrival" at the gas station, correlates with low fuel reserve and unlocks the gas inlet. The petrol pump recognizes that your car is within the necessary proximity to the dispenser and recalls your choice for unleaded product. The nozzle from dispenser discovers the gas inlet, and commences fill-up, when your inlet allows, and confirms that the nozzle delivers petrol, not diesel. Once refueling completes, you see a green icon on your dashboard. You receive a SMS, indicating completion of fueling. The latter auto-triggered a financial transaction, to match the cost of fuel. Your bank confirms payment over iSkin or a smartphone app. It also informs your wife (authorized routing).

The convergence of IoT, digital twins and blockchain is evident. The ecosystem of enterprises, when dissociated by *modular* structures and associated by function, in an operational sequence, presents a series of steps, which can be sub-divided into "blocks" which are not only things/objects but software Agents, work units, process, authentication, authorization, decisions, outliers, feedback, security, metrics and dependencies.[45]

Who will build these blocks?

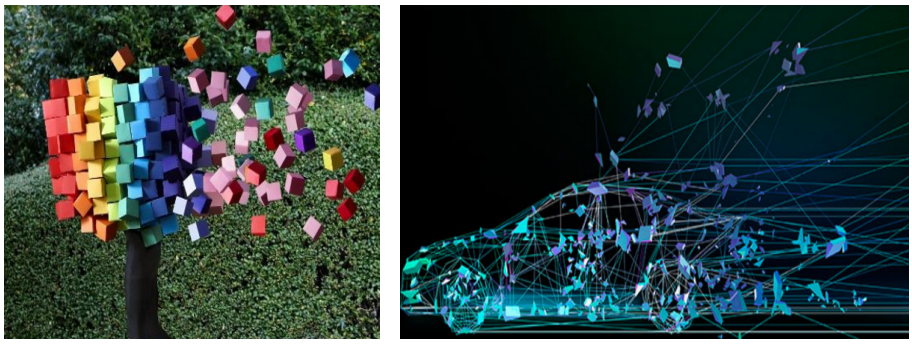


Fig. 3 - Blocks – a seamless operation represents an array of functions converging from diverse partner companies[46] illustrations extracted from: left image from [3] and right image from [4]

As it is with IoT, there will not be any one industry, or company, which may claim to be the front-runner. The modular building blocks, for the domains spanning and *overlapping* IoT, digital twins and blockchains (not limited to financial transactions) are quintessential to the global economy. The idea of a distributed team, or teams entrusted to architect these blocks, may seem reasonable. The fractured state of the world and the intrinsic impact of natural language (in)competencies on creating semantic dictionaries and ontological frameworks introduces severe socio-technical incongruencies. Hence, credible academic leadership of industry-government consortia, in partnership with global organizations or standardization bodies, may be a prudent option.

If a few global alliances create the blocks, and agree to establish the tools for interoperability, then we may anticipate a future global repository[47] for these digital blocks to accelerate global digital transformation. The ubiquitous need for principles and practice of connectivity[48] is salient to this discussion. The value expected from connectivity, assumes operation of multiple ecosystems, which must *converge*, to *deliver* the value. Table 1 suggests some of the layers, and components, necessary for this engineering ecosystem.

Local and global providers, who supply products and services germane to each layer (and several sub-layers within each layer), may not practice standard operating procedures (SOP). When volatility is the norm, it is wishful to expect SOP or expect groups in distant corners of the world to conform. The task of interoperability, and the ability to automate interoperability by **"discovering"** what is necessary to commence communication or cross-check resources, becomes pivotal. It is a tool which is not yet available. Do we need this tool to ***discover*** and replenish the gaps, for functional interoperability to commence?

[3] https://i.io.ua/img_su/small/0010/63/00106374_n1.jpg
[4] https://medium.com/vlb-token/blockchain-will-make-cars-safer-and-cheaper-bfda499a9f57

Table 1. Layers, and components for this engineering ecosystem

01	I	Infrastructure	Scaffolds which includes energy, internet engineering, telco networks
02	T	Telecommunications	Backbone of connectivity which enables location agnostic operations
03	P	Protocol	Transaction triggered response operating agnostic of protocol-specificity
04	D	Discovery	Blocks/entities must find each other in order to communicate (think RDF)
05	C	Connectivity	Glue that enables digital transformation unless restricted by boundaries
06	S	Sense	Data acquired from points of interaction to understand status / attributes
07	R	Response	Analytics driven action/actuation based on integrating diverse knowledge
08	O	Operate	Outcome as pre-determined or change direction if influenced by factors
09	A	Adapt	Ability to remain dynamic and agile by recalibrating operations (eg SCM)
10	K	Knowledge	Learnings from operation (store/delete), dissemination, update analytics

It is expected that automating interoperability, may lead to auto-generation of APIs when interfaces "discover" that they cannot "talk" between models, data holders, tables, devices. It may trigger an automated mechanism to understand *what needs to be understood* between the systems, and then obtain the "glue" (for example, creates remote function call to source a "patch" from a repository) to facilitate interoperability. APIs are *enablers* of interoperability but creating API is *not* synonymous with *instituting* interoperability between systems. True interoperability involves the arduous task of semantic interoperability between systems, to facilitate data-driven multi-system performance optimization.

If someone speaks to me in Hebrew, I must know that I am *listening to Hebrew* before using Google to communicate in Hebrew. If I had a tool to ***auto-detect*** languages then it could help trigger (CNN/RNN[49]) Hebrew translation on my iPhone. An "avatar" or Siri or Cortana or Alexa, can then, guide my exchange.

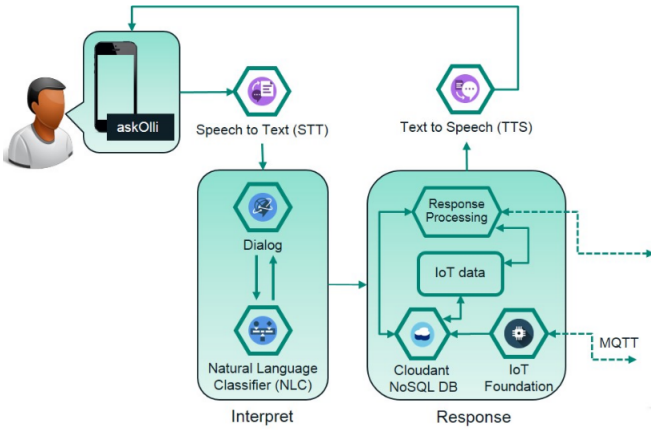


Fig. 4 - Watson Speech to text (STT) (illustration adapted from [5])

[5] https://www.linkedin.com/pulse/meet-olli-fusion-autonomous-electric-transport-watson-kalyanaraman/

Discovery tools for auto-detection of attributes, and characteristics ***between*** entities, Agents, and models, are a core part of the digital-by-design metaphor, for example, IoT. Research in connectivity may help develop a new generation of ***digital semantic sensors*** to sense (what we may not know) *what needs sensing*. The concept of *"sensing the need to sense"* moves beyond semantic detection and introduces cognition. What we need is a ***cognitive compass.***

The process of discovery, in addition to other elements, is a mix of semantic and cognitive modules. The inability to discover objects or identifying the wrong object or perturbing time-critical discovery (implants, medical devices) are potential pathways to compromising safety, security, privacy, authorization and cybersecurity. Intruders may be sophisticated to avoid semantic detection (5, 50 and 500, are semantically, numbers, in different ranges). The importance of cognition and need to introduce cognitive firewalls[50] may be quintessential. Cognitive "supervisors" are necessary to keep an eye on semantic processes.

Thus, claims for ubiquitous computing, first, must find tools for discovery. The illusion of trillions of "things" connected via IoT are delusional and hyperbole marketed by uninformed publicists. Unless objects can safely ***discover*** each other, they may not connect (assuming that connectivity is protocol agnostic). Implementing tools and technologies[51] central to discovery, and diffusion of cybersecurity as a service, may be required to accelerate digital transformation.

Digital twins may depend on safe "discovery" using semantic properties and cognitive rules for auto-configuration (think *ad hoc* auto-configuration of mesh networks) to create the desired assembly (machine floor, medical devices attached to patient, turbines, water purification). Digital twins will inherit attributes of the physical components and physics of the system. Ontology based semantic interoperability by design depends on entity level relationships. Distributed digital twins created by different sources, approved by cognitive supervisors, and connected by secure systems, may communicate, and form *swarms,* to help us make better decisions (one agent vs an agency or one ant vs a swarm of ants) employing the popular concepts of swarm intelligence.[52]

Fraternal Twins: The First Born – Digital or Physical? A century ago (1916), a theory about freemartins[53] (the female of the heterosexual twins of cattle) generated interest about rare monozygotic twins[54] in cattle. This led to the discovery of Müllerian Inhibiting Substance[55] (MIS). Pioneering research[56] by Patricia Donahoe[57] is beginning to unravel the role and therapeutic potential of MIS. It appears that the human genetic program is inherently female[58] (which came first - male or female, the chicken or the egg). If the fetus was left to differentiate without MIS, fetal development of müllerian ducts will produce a female child. That is, the "default" option of human genetics is programmed to produce females. Males exist due to inhibition of the development of müllerian ducts by MIS and differentiation of the Wolffian ducts by fetal testosterone. Females have evolved by design but males appear to be a modification or a by-product of evolution.

This very distant digression is intended to make the point that a fundamental plan, a base, exists in nature. The female plan is copied (duplicated) to produce the male, albeit,

with modifications, catalyzed by a starter dose of MIS.

The concept of digital twins assumes we are *creating* a digital duplicate of the physical entity. But, the *born digital* metaphor may be, in reality, *digital conception*. In the industrial arena "things" may not be created without an engineering plan, technical specs and CAD/CAM models. The physical entity must be *conceived* as a digital model, before birth of the product. In the world of machines and parts, being *conceived as digital* ***is*** *the design*, to use a pre-natal metaphor. The physical entity is the post-natal stage, metaphorically. A plethora of exceptions may prove the rule. One such case are add-ons, for example, humans (and animals), attached to medical devices[59] in homes or hospitals. We can create digital twins of this *combined* state, to monitor their physiology, but that "twin" or digital proxy may not be referred to as *born* digital. In this instance, for medical purposes, we can think of digital twins as a combinatorial outcome, for monitoring and acquisition of data. By closing the loop and enabling feedback from medical digital twins, we can save lives, thousands, or even millions, of lives.[60]

Think about a helicopter[61] which may not be created as a physical entity unless we have a CAD/CAM (digital) version and create a simulation (using differential equations) to test the operation (rotation of the blades for lift-off). In recent models from manufacturers (Boeing 787), the pilot is subservient to the simulated model in the auto-pilot. An image conjured by the latter generated the apocryphal statement that in the airplane of the future there may be only two living creatures in the cockpit. A pilot and a dog. The role of the dog is to stop the pilot from touching the controls. The role of the pilot is to feed the dog.

If we reverse the logic of the digital twins we have discussed thus far, one might propose the digital blueprint as the primordial layer and the physical entity to be the fraternal twin (perhaps with limited mobility, if thinking about machines).

The digital blueprint and the simulated models[62] which exists today, may be rapidly engineered with data feeds from the physical operation, to approach the "live" concept of digital twins. In proposing this *modus operandi*, we move closer to the domain of cyber-physical systems[63]. Time dependencies create the need for time guaranteed software[64] which can understand the semantics of time and is protected from cyberthreats or time spoofing, by using cognitive firewalls, if time criticality is pivotal for its operation. For example, from (t=0) the decision to apply the brakes to the actual act of braking (t=n) to stop an automobile.

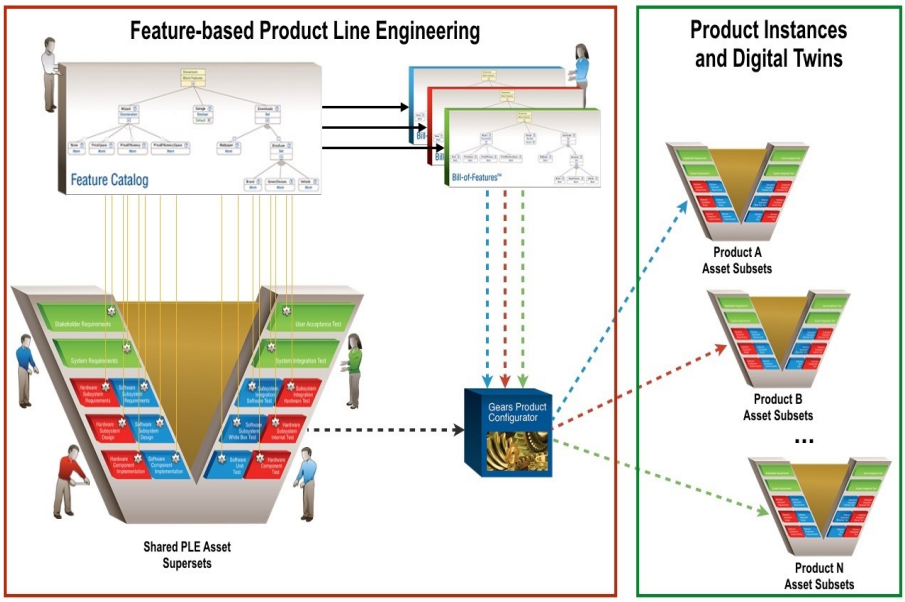


Fig. 5 – Feature Based Production Line Engineering (illustration extracted from [6])

The old world of engineering V models (Fig 5), spanning requirements, design, test, to user documentation. The upper tiers of the V represent the modeling and design phases where engineers build features based on product requirements, which flow to subsequent phases of the development, and manufacturing lifecycles. Individual features of a product are represented in the software[65] as pieces of modular source code that can be "turned" on or off, allowing assets to be generated based on a particular set of features (variant configuration). This accumulation of source code-based assets provides the foundation for creating physical products, but may be leveraged simultaneously to create a corresponding digital twin. Thus, the physical product is born digital. The digital twin can be bound using unique RFID identifiers, or other forms of component serial numbers, once the device is manufactured, and may operate through intelligent PLM platforms, throughout the product's life. The latter may ensure that the digital twin or the digital proxy, is auto-updated. Standards and certifications are key to adoption.

Confluence of Swarms Through Data Fusion – All Advantages Are Temporary. The digression about the conceptual see-saw, about whose twin is it anyway, is a thread of reasoning, not a barrier. It may make it easier to create the open repositories needed in the process of digital transformation. The road ahead for digital twins, digital proxies and digital transformation is fraught with problems and also brimming with potential. Driving fusions (please see illustrations below) through collaborative ecosystems may be one path to profit. There may not be a "winner takes it all" version in a cognitive digital twin economy.

[6] https://www.slideshare.net/ArasPLM/product-line-engineering-meets-plm (slide 14)

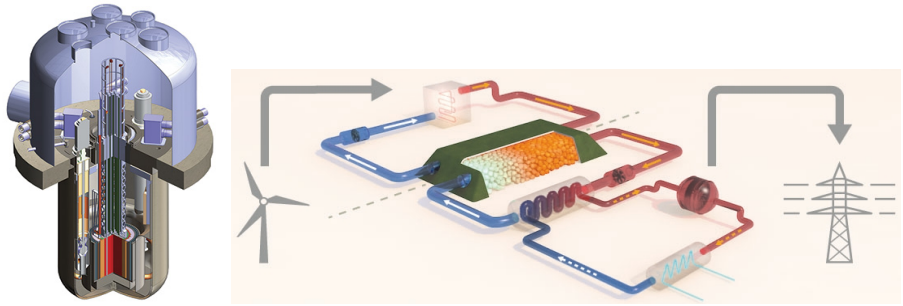


Fig. 6 – Digital Transformation: Energy Equilibrium – Elusive Quest for the Digital Mitochondria? To maintain homeostasis of energy production, distribution and load balancing. Adapting to multiple sources and types of energy obtained from diverse producers (domestic, commercial) with variable end points (homes, roadside charger, factories, mobile delivery). (illustrations extracted from: left image from [7], right image from [8])

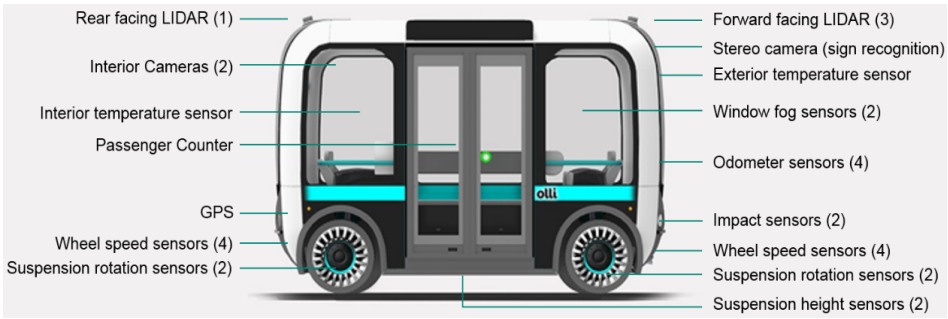


Fig. 7 – Digital Transformation: The Transportation Alloy – Alliance of Autonomy, IoT, Telecommunications and 3D Printing [66] (illustration extracted from [9])

To profit from fusion in the digital-by-design era, collaborative efforts[67] may be one way forward. These examples of convergence (above) may be coupled with their operational digital twins or digital proxies. Information arbitrage from a wide cross-section of similar operations (from many devices) may provide a glimpse of patterns, which were previously unobtainable, due to the focus on one or few operations.

Hence, standards are key, followed by interoperability between standards and other facilitators (converters, adapters, translators, multi-homing) to increase connectivity and reduce incompatibility. The transaction cost may increase and reduce margin of profit, incur losses and downgrade the brand, if architectural and/or structural discrepancies, continue to pose barriers to function and/or outcome, expected by the customer.

A typical laptop deals with 250 compatibility standards. About 20% of the standards

[7] http://www.world-nuclear-news.org/NN-TerraPower-brings-BandW-on-board-180214ST.html
[8] http://rief-jp.org/ct4/71847
[9] https://www.linkedin.com/pulse/meet-olli-fusion-autonomous-electric-transport-watson-kalyanaraman/

are from individual companies, while 44% are from consortia and 36% from accredited standards development organizations. The complexity in laptops will be dwarfed by the variability expected for Digital Twins. But the use of ICE (Internalizing Complementary Externalities) like principles may evolve to create working solutions.[68]

Complementarity, compatibility and interoperability, assures us that we can expect visibility not only of one operation (which is what one industry or one team may monitor) but a group of hundreds or thousands of such operations. This massive data set may help us to understand patterns, predict faults, detect anomalies and use true "big" data, data curation and higher level metadata, to feed other functions, such as data driven policy, security threats and intruder detection using cognitive pattern analytics.

Consider the cartoon (below, left) of a physical event and assume that we have a digital twin of that operation that an analyst or manager can remotely view to "see" or monitor the physical operation in progress.

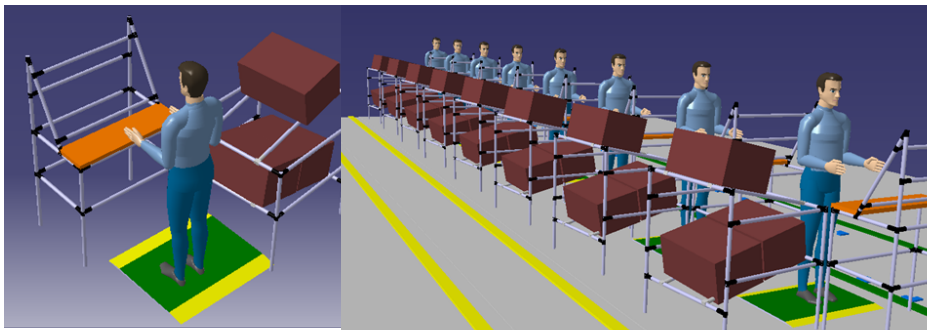


Fig. 7 – Physical System (cartoon adapted from illustrations by Lego®)

But, if the physical event (above, left) is not an isolated scenario, then digital duplication may generate (above, right) a form of digital transformation which may be representative of a digital swarm or flock.[69]

This digital vision of aggregated events, may generate big data and metadata, from precision patterns, which may be extracted or extrapolated with respect to process, performance and profitability. Any one instance may not offer sufficient incisive insight, but applying the principles of swarm intelligence to hundreds of instances, may provide wealth of information (not only data) which could enhance decision support systems and improve the monetization[70] potential.

Fig. 8 – Robots (illustration extracted from [10])

Swarms of robots (networks, connected via combination of cloud, fog, mist) are likely to generate massive amounts of data. This data, if acquired, analyzed, and used in feedback control, may optimize process, reduce waste and compress production time. Use of "intelligent" decision systems platforms, various levels of automation, and predictive analytics, may transform the concept of 'zero' downtime to manufacturing reality, more or less.

Data from swarms may improve detection of anomalies, predictive analytics (if equipment needs a part or replacement) and errors or *red herrings* in the swarm may indicate security threat, breach or may elicit unusual activity alerts. The blockchain-like digital ledgers, in the backbone of the digital twins, may be useful in identifying the point of anomaly and associated objects or humans in the loop. Combined with advances in hack-proof[71] code and cognitive firewalls, this approach may add a new dimension to systems cybersecurity.

The swarm and flock approach, if applied to the developing notion of smart cities, may offer relatively precise information, from digital twin operations of scale-free networks in urban digital transformation. Monitoring digital proxies of water valves, in operation, to control or regulate water waste, water security and water pollution. From an engineering systems point of view, the digital abstraction is applicable to city-level applications. Cities are inter-dependent cascade of systems and networks[72] such as energy networks, traffic networks, sewer networks, communication networks, road networks and emergency response networks. The latter can make a difference between life and death.

The vision of network convergence may be crippled and remain impotent without architectures which are resilient, fault tolerant and uses standards which are dynamic. But, interoperability between standards are rather difficult when competition fuels mistrust, spurs acrimony and short-term profits are the life-blood of the industry. Digital transformations calls for confluence of ideas beyond the horizon and new roads to reach the luminous summit. Investment in scientific[73] vision is often viewed with

[10] https://www.autodesk.com/solutions/robot-programming-software

reservation, excessive caution, undue skepticism and even disdain. The latter is most unfortunate for the progress of civilization.

Digital twins, IoT, blockchains, AI and swarm intelligence may re-define our imagination and future vision of globalization. *That* sense of the future requires businesses to re-think about ROI and profits, re-configure micro-payments and micro-revenue models, but not at the expense of investment in R&D. The latter is quintessential for innovation, and a tool to catalyze the principles of digital economics, to accelerate globalization.

In part, this idea originates from Marshall McLuhan[74] that anyone, anywhere, may consume the same information. Digital Twins are another example of how this idea may be the reality for humans and machines, at multiple levels.

For example, a manufacturing plant in China, may be operating a component or machine sub-system, (atoms), which is represented by the Digital Twin or the data model of the digital proxy (bits). The global supply chain analyst, in India, monitors the status of the part via PLM. SCM intelligent decision support can trigger a replacement part from a supplier in Tampere, Finland or the component may be 3D printed by DDM Systems in Atlanta, GA and shipped to the factory in Dalian, China.

Taking this idea one step further, if the transport cost of bits approach zero, the transport to Dalian may be replaced, by sending the bits from the 3D architect in USA, to the 3D printer in Dalian, China, to 3D print the part. Digital Twins, through the process of digital transformation, shall lead us, perhaps, to the true digital economy, which once was an idea, implicit in the trade model, proposed by Paul Krugman[75], 40 years ago.

3 Conclusion

At the dawn of the 21st Century, the internet was viewed by different groups to serve different functions. In some cases, it served as a storage platform[76], others perceived it as a copying machine[77], and economists[78]explored its ability to reduce transaction cost (eg, communication, replication, transportation, tracking, verification, search) and democratization of information, as a catalyst for global economic growth.

Digital transformation, in the 21st Century, is the ability to represent atoms, in terms of bits. It stems from the seminal work by Claude Shannon[79] which grew roots during the 20th Century (Shannon information theory).

Digital transformation is made possible by the internet. Digital Twins and its "lite" version, digital proxy, are a part of the fabric of digital transformation, likely to affect most enterprises, worldwide, willing to duplicate the physical model for remote monitoring, viewing and controlling, based on a digital format (iPhone).

It is almost justified to think about the internet as a "giant copying machine" which can "copy" physical objects (atoms), to generate corresponding Digital Twins, a representation of information about the atoms, in terms of bits. Hence, we are not dealing with entirely new concepts, just new modes of expression.

Digital Twins are akin to the "emperor's new clothes" which are made of pre-existing conceptual yarns. We have added new vernacular and embedded the fabric with potentially new widgets (for example, the use of blockchain, as a verification tool).

In this article, we call for an open source approach, to create the "blocks" or modules, necessary to democratize the *ad hoc* and *en masse* configuration of Digital Twins, by ***non-experts***. The latter may no longer limit the use and application of Digital Twins in the hands of experts, alone.

Digital Twins may evolve as a tool, unconstrained by domains, beyond the boundaries of high performing economic regions, and contribute to economic growth, through open source platforms for digitization. Economic[80] growth from such "digital dark matter" and other intangible benefits to the global economy, remains unmeasured. The impact from Digital Twins, digital proxies and digital duplicates, and cumulative benefits, may be only limited, by our imagination.

Industry must embrace change, imagine paths to reduce transaction cost, and shoulder the need to balance uncertainty, which may accompany the dynamics of digital economics. Leaders must proactively support the call for creating structures, necessary to pursue collaborative initiatives[81] through investment in massive workforce development, skills training, digital learning[82], education, research, institutional advancement and the pursuit of dignity.

---

[1] Nicholas Negroponte (1996) Being Digital, Vintage Books
[2] Neil A. Gershenfeld (2000) When Things Start to Think, Henry Holt and Company
[3] www.simonandschuster.com/books/The-Path-Between-the-Seas/David-McCullough/9780743262132
[4] http://bit.ly/EYE-in-AI
[5] http://www.politico.com/agenda/story/2015/06/internet-of-things-privacy-risks-security-000096
[6] https://www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/popular-chemistryprize2016.pdf
[7] http://uberty.org/wp-content/uploads/2015/07/Norbert_Wiener_Cybernetics.pdf
[8] www.whitehouse.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf
[9] www.whitehouse.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/national_ai_rd_strategic_plan.pdf
[10] www.ieeecss.org/sites/ieeecss.org/files/documents/IoCT-Part3-02CyberphysicalSystems.pdf
[11] http://leeseshia.org
[12] https://cse.nd.edu/seminars/cse-seminar-series-rahul-mangharam
[13] https://s3.amazonaws.com/nist-sgcps/cpspwg/files/pwgglobal/CPS_PWG_Framework_for_Cyber_Physical_Systems_Release_1_0Final.pdf
[14] Lee, E.A. (2015) The Past, Present and Future of CPS. Sensors 15 4837-4869 http://www.mdpi.com/1424-8220/15/3/4837
[15] https://thingful.net/
[16] http://www.computerworld.com/article/3076213/internet-of-things/the-iot-past-present-and-future-an-interview-with-professor-sanjay-sarma.html
[17] https://en.wikipedia.org/wiki/Sally_(short_story)
[18] http://digitalcollections.library.cmu.edu/awweb/awarchive?type=file&item=34057
[19] Ishii, H. and Ullmer, B. (1997) Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms in Proceedings of CHI'97 (ACM, March 1997) http://tangible.media.mit.edu/person/hiroshi-ishii/
[20] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.43.130&rep=rep1&type=pdf
[21] https://www.ics.uci.edu/~corps/phaseii/Weiser-Computer21stCentury-SciAm.pdf

[22]http://cocoa.ethz.ch/downloads/2014/06/None_MIT-AUTOID-WH-001.pdf
[23]http://autoid.mit.edu/people-2
[24] https://www.technologyreview.com/s/601013/the-internet-of-things-roadmap-to-a-connected-world/

[25]https://www.ntia.doc.gov/files/ntia/publications/iot_rfc_june_2016_georgia_tech_cdait_alain_louchez.pdf
[26]https://www.whitehouse.gov/the-press-office/2016/07/15/fact-sheet-administration-announces-advanced-wireless-research
[27]https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf
[28]http://ucsdnews.ucsd.edu/pressrelease/keeping_track_of_time_in_cyber_physical_systems
[29]http://www.nhk.or.jp/8k/history/index_e.html
[30]http://news.mit.edu/2012/auto-id-cloud-of-things-big-data
[31]http://ubicomp.oulu.fi/files/cscwd13.pdf
[32]https://hal.inria.fr/hal-01004489/file/city06-petrolo.pdf
[33]https://www.apan.net/meetings/Nantou2014/Sessions/IoT/Cloud-of-Things-APAN38-2014.pdf
[34]http://bit.ly/Block-Chain
[35]https://newsroom.accenture.com/content/1101/files/Cross-FSBC.pdf
[36]http://www.zatar.com/blog/avatars-and-iot-architecture
[37]https://hbr.org/2014/11/setting-standards-for-the-internet-of-things
[38]MPEG http://oxygen.csail.mit.edu/videosketching.html ● CSAIL http://oxygen.csail.mit.edu/Overview.html
[39]https://arxiv.org/ftp/arxiv/papers/1609/1609.05774.pdf
[40]www.w3c.org
[41]Datta, S. (2002) Agents - http://dspace.mit.edu/handle/1721.1/41914
[42]Minsky, Marvin (1985), Society of Mind - http://www.acad.bg/ebook/ml/Society%20of%20Mind.pdf
[43]http://spectrum.ieee.org/computing/networks/metcalfes-law-is-wrong and http://www.dtc.umn.edu/~odlyzko/doc/metcalfe.pdf
[44]http://www.spiegel.de/auto/aktuell/bundeslaender-wollen-benzin-und-dieselautos-ab-2030-verbieten-a-1115671.html
[45]http://esd.mit.edu/WPS/2007/esd-wp-2007-17.pdf and http://dspace.mit.edu/handle/1721.1/41902
[46]http://qz.com/801640/darpa-blockchain-a-blockchain-from-guardtime-is-being-verified-by-galois-under-a-government-contract/
[47]www.scientificamerican.com/article/world-repository-of-human-genetics-will-move-to-amazons-cloud/
[48]Principles and Practice of Connectivity (pdf of pptx) https://dspace.mit.edu/handle/1721.1/104429
[49]https://dspace.mit.edu/handle/1721.1/101151 and https://arxiv.org/pdf/1411.4555v2.pdf as well as https://arxiv.org/pdf/1603.08270.pdf
[50]https://dspace.mit.edu/handle/1721.1/104456
[51]http://oxygen.csail.mit.edu/videoh21visit.html and http://oxygen.csail.mit.edu/videomultilingual.html
[52]http://www.antoptima.ch/pdf/pr_harvardbusiness_0105.pdf
[53]https://www.jstor.org/stable/pdf/1641047.pdf
[54]http://www.nature.com/hdy/journal/v2/n1/pdf/hdy19481a.pdf
[55]Price JM, Donahoe PK, Ito Y, Hendren III WH (1977) Programmed cell death in the Mullerian duct induced by Mullerian inhibiting substance. American Journal of Anatomy 149 353–375
[56]http://press.endocrine.org/doi/pdf/10.1210/edrv.22.5.0445

[57] http://hsci.harvard.edu/people/patricia-k-donahoe-md
[58] https://www.ncbi.nlm.nih.gov/pubmed/7828438
[59] http://mdpnp.mgh.harvard.edu/
[60] http://www.bmj.com/content/353/bmj.i2139
[61] http://www.da-vinci-inventions.com/aerial-screw.aspx
[62] https://www.modelica.org/
[63] https://www.seas.upenn.edu/~rahulm/
[64] https://www2.eecs.berkeley.edu/Pubs/TechRpts/2008/EECS-2008-72.pdf
[65] http://www.biglever.com/extras/PLE_LifecycleFramework.pdf
[66] http://www.theverge.com/2016/6/16/11952072/local-motors-3d-printed-self-driving-bus-washington-dc-launch
[67] https://www.regulations.gov/contentStreamer?documentId=NHTSA-2014-0022-0001&attachmentNumber=1&disposition=attachment&contentType=pdf and http://vistadataproject.info/
[68] http://people.bu.edu/tsimcoe/documents/working/FourPaths.pdf
[69] Berrondo, M. and Sandoval, M. (2016) Defining emergence: Learning from flock behavior. Complexity 21 69–78 doi:10.1002/cplx.21711
[70] http://www.icosystem.com/about-us/
[71] https://www.quantamagazine.org/20160920-formal-verification-creates-hacker-proof-code/
[72] http://journals.aps.org/prx/pdf/10.1103/PhysRevX.6.011036 and http://dx.doi.org/10.1063/1.4962970
[73] www.seattletimes.com/opinion/editorials/another-nobel-prize-for-uw-scientist-illustrates-value-of-pure-science
[74] McLuhan, M. (1964). Understanding Media: The Extensions of Man. http://robynbacken.com/text/nw_research.pdf
[75] Krugman, P. (1979). A model of innovation, technology transfer, and the world distribution of income. Journal of Political Economy, 253–266. http://pioneer.netserv.chula.ac.th/~kkornkar/inter%20trade%20course/a%20model%20of%20Innovation.pdf
[76] http://xml.coverpages.org/PML-MIT-AUTOID-WH-005.pdf
[77] Shapiro, C. and H. R. Varian (1999). Information rules: A strategic guide to the network economy. Harvard Business Press. http://faculty.csuci.edu/minder.chen/MBA550/reading/hal-varian-information-rules-chapter-1.pdf
[78] http://www.nber.org/papers/w23684
[79] http://www.itsoc.org/resources/Shannon-Centenary/shannon-work-legacy-paper
[80] Greenstein, S. and F. Nagle (2014). Digital dark matter and the economic contribution of Apache. Research Policy 43(4), 623–631. https://pdfs.semanticscholar.org/32ff/6098dc5d26551107935b78ef4a34f0b9aece.pdf
[81] http://autoid.mit.edu/iot_research_initiative
[82] http://odl.mit.edu/

Journal of Innovation Management
JIM 5, 3 (2017) 34-54
HANDLE: http://hdl.handle.net/10216/107952
SM: Feb/2016 AM: May/2017

Assessment of Technological Innovation Climate in Organizations

Refaat Hassan Abdel-Razek[1], Fawzah Battal Alharbi[2]

[1] Professor of Engineering Management, College of Engineering,
University of Sharjah, Department of Industrial Engineering & Engineering Management,
Sharjah, United Arab Emirates
rabdelrazek@sharjah.ac.ae

[2] Graduate of Dept. of Technology & Innovation Management,
College of Graduate Studies, Arabian Gulf University, Bahrain

Abstract. The ability to develop a work environment climate supporting technological innovation does not occur suddenly or unexpectedly. The objectives of this paper is to assess the technological innovation climate in one of the largest oil and gas company in the world, to compare the results with published standards, and to suggest recommendations to improve the innovation climate in the company. The study used the situational outlook questionnaire to assess nine key dimensions of innovation climate. The results showed that the extent to which each of the nine dimensions is applied were: debate (70%); idea support (67%); challenge/involvement (67%); trust and openness (59%); freedom (57%); idea time (56%); playfulness/humor (52%); risk taking (50%) and conflict (46%). These results were compared with published norms and the results revealed that the company is categorized as innovative in debate, idea time, idea support and trust; categorized as average in challenge and risk taking; and as stagnated in freedom, playfulness and conflict. The comparison using the t-test confirmed the results. Recommendations and details of the actions required for improvement were outlined.

Keywords. Creativity, Innovation Assessment, Innovation Climate, Innovation Culture, Innovation Management.

1 Introduction

Improving work environment in organizations by buying comfortable furniture and luxurious offices are not making innovation or enhance the stuff creativity. The most important factor as proposed by Parther (2010) is “establishing a climate for innovation". A research by PricewaterhouseCoopers (2007) examined the gaps between the most innovative companies and the lowest performance from among the Times Top 1000 organizations in the United Kingdom. The study identified three basic capabilities that characterized the more successful organizations: having a deliberate process for idea management, building a creative climate and following an inclusive approach to leadership. A report made by UNESCO (2010) stated that even oil-rich-Arab states need innovation. Despite the need for innovation, the literature shows that oil-rich-Arab states lag far behind developed countries in terms of science and technology (Sanyal & Varghese, 2006; UNESCO, 2010). Abdel-Razek and Alsanad

ISSN 2183-0606
http://www.open-jim.org

(2014) stated that all developing countries fall far behind developed countries in terms of technology and innovation. Abdel-Razek and Alsanad (2015) showed that progress in modern technology is the only way for developing countries to join the league of developed countries. Alabbas and Abdel-Razek (2016) emphasized the importance of the evaluation and improvement of creativity and environment climate in organizations in order to improve their innovation and consequently their technology. Abdel-Razek (2014) and Alsanad and Abdel-Razek (2016) demonstrated that there is little current published literature that investigates the several research areas of innovation including the assessment and methods of improvement of creative and innovation climate in organizations in developing countries generally and in the Arab countries specifically.

Climate can be defined as the recurring patterns of behavior, attitude and feeling that characterize life in the organization (Tidd and Bessant, 2013). Climate of innovation and creativity is the climate that supports the development, assimilation and utilization of new and different approaches, practices and concepts. It is also the climate which promotes the generation, consideration and use of new products, services, and ways of working (Isaksen and Tidd, 2006). Early creativity research focused on individual characteristic that predisposed people to achieve high levels of creativity while more recent research has considered the effects of environment on individuals' ability to be creative (Adolfsson, et al. 2013). The most innovative companies of the future will be those, which have created the appropriate cultures and climates.

The objectives of this paper is to assess the technological innovation and creativity climate in the largest oil and gas organizations in the middle east, and one of the largest in the world, to compare the results with published standards, and to suggest recommendations to improve the innovation climate in the company.

2 Dimensions of Innovation Climate

Amabile, et al. (1999) categorized the innovation climate into four dimensions: management practices; organizational motivation; resources; and outcomes. McAlindon (2004) defined the characteristics that can be used to measure the innovation climate as: risk-taking, rewards, empowering, objective measurement, feedback, turbulence, interdependence, decentralization and cosmopolitan. Hoe (2011) discussed and proposed the factors to be useful in determining an organization innovation's climate as: shared vision, management support, community, individual creativity, implementation and motivators. Hunter, et al. (2005) claimed that there are more than 40 different conceptions of innovation climate and ways of assessing it. Hunter et al. (2007) in their analysis of 42 studies on the climate of creativity and innovation found that the studies that are based on a well-developed standardized instruments provides noticeable and stronger effects, than did the studies based on locally developed instrument. Tidd and Bessant (2009) stated six critical dimensions that influence the climate of innovation: trust and openness; challenge and involvement; support and space for ideas; conflict and debate; risk taking; and freedom.

3 The Research Tool

There are a number of surveys and approaches to assess the organization climate for innovation. Mathisen and Einarsen (2004) conducted a survey for the best known and most used tools to asses innovation climate in organizations and reported four tools: the siegel scale of support of innovation (SSSI) (Siegel and Kaemmerer, 1978); team climate inventory (TCI) (Anderson and West, 1996); assessing the climate for creativity KEYS, originally called the work environment survey (Amabile, et al. 1999); and the situational outlook questionnaire (SOQ) (Isaksen, et al. 1999). These tools were critically reviewed. SSSI and TCI are not considered as tools for assessing technological innovation climate; KEYS needs more revision and more studies to assess its validity (Mathisen and Einarsen, 2004); and SOQ measures the perceptions of employees of the climate for creativity, innovation and their readiness for change within their immediate work environment. In addition, Isaksen and Ekvall, (2013) reported that the reliability of the SOQ was examined using a sample of 3491 individuals from fifty-two different organizations and they stated that the results of Cronbach alpha for the all the nine dimensions of innovation climate have greater than 0.70 values of alpha, which indicate acceptable levels of reliability.

In this research, the SOQ was selected as the instrument for this research and obtained the approval from Creative Problem solving Group, Inc. (CPSB) to use the (SOQ). The survey questionnaire consists of 53 statements (including 3 open-ended questions) that assess nine dimensions of organizational innovative climate: challenge & involvement, freedom, trust / openness, idea time, playfulness / humor, conflict, idea support, debate, and risk-taking. The nine dimensions are scored on a scale from 0 to 300. Each of the nine dimensions has five to seven constituent items.

4 The Company and the Participants

4.1 The company

The case company is a Saudi oil company and a world leader in exploration, production, refining, distribution, shipping and marketing. The company is a state-owned oil company of the Kingdom of Saudi Arabia, manages more than 113 oil and gas fields in Saudi Arabia. It is the world's fourth-largest gas reserves, with 282.6 trillion cubic feet and world's top exporter of natural gas liquids. The average daily crude production in 2012 was 9.5 million barrels per day and the total oil production for the year was 3.5 billion barrels, about one in every eight barrels of the world's crude oil production. The company headquarter is in Dhahran and its operations span the globe through Saudi Arabia, North America, Europe and Asia. By December 2012, the company has more than 54,000 employees across Saudi Arabia, North America, Europe and Asia. The company is putting innovation and creativity as one of its priority.

The company organizational chart was studied and analyzed. The technology management division, one of the main company's divisions, was selected as the representative sample of the company. This division consists of two groups and one department: the innovation and knowledge management group, the intellectual assets management group, and the consulting services department. The sample of the study

included all the 45 employees in the selected divisions' two groups and the department. They consisted of all the 15 employees from the innovation and knowledge management group; all 13 employees from the intellectual assets management group; and all the 17 employees from the consulting services department.

4.2 Characteristics and distribution of the participants

The total number of distributed questionnaires was 45 and the number of valid returned questionnaires was 42 with a response rate of 93.3%. The profile of the respondents is looked upon in terms of job title, age, gender, educational level, and length of stay in the company and in current position. The analysis of the data shows that most of the employees who participated in this research were engineers (88.1%), the others (11.9%) were non engineers, such as: assistant control advisor (2.4%) contract advisor (2.4%) cost group (2.4%) pipeline consultant (2.4 %), PQP analyst (2.4%). The mean age of the participants was 38 years old with a range from 23 to 53. Only two of the respondents were females while forty of the responses were males. The respondents were categorized according to their educational level; four were PhD holders, 13 Master holders, 4 PG degree holders, 19 Bachelor degree holders and 2 College/ two years degree holders. 11.9% of respondents have more than 20 years in the company while 42.9% spent from 10 to 20 years, 26.2% spent from 5-10 years, 7.1% had service from 2-5 years, 7.1% from 7 months to a year and 2.4% had service for 6 months or less. The number of years of service in the currents position was also obtained. 11.9% of the respondents spent from 10 to 20 years in their current position, 26.2% from 5-10 years, 21.4% from 2-5 years, 11.9% from 7 months to one year, and 14.3% had service for 6 months or less. The analysis indicates that the majority of the respondents are knowledgeable enough to the climate of the company; it also indicates the maturity of the respondents particularly in terms of experience; and that the majority are knowledgeable enough to the climate of the company, specifically in terms of its innovation and technology.

5 Assessment of the Innovation Climate in the Company

The respondents were asked to respond to the extent to which each one of the 53 statements is applicable in their organization. Each one of the nine climate dimensions has five to seven statements. The respondents rated each of these statements. Table (1) shows the results of how the respondents assess their climate for technological innovation within their current work environment. The resulted score for each dimension was ranging from 0 to 300. The higher the score in the 8 dimensions (challenge and involvement, freedom, trust/Openness, idea time, idea support, risk taking, playfulness & humor, and debates) means the better climate and for one dimension (conflicts) the less score reflects better climate. The overall scores for each dimension were calculated. Table (2) shows the mean and standard division calculated for each dimension of the innovation climate for the 42 participants.

The average scores represent the respondents' assessment of the extent to which the behaviors described in each dimension are present in their company's climate. The

results reflect the average score and level of application, as a percentage, for each dimension of the innovation climate in the company and are illustrated in Figures 1 and 2. The results revealed that the debate comes as the most applied dimension with 70%, the two dimensions of idea support and challenge / involvement are applied in the company at the same level of 67%, the trust / openness innovation dimension is applied with 59%, freedom is applied with 57%, idea time with 56%, playfulness / humor with 52%, risk taking with 50% and conflict -which is a negative dimension- is applied with 46%.

Table 1. Assessment of the technological innovation climate dimensions by each respondent

Dimension / Respondents	Challenge/Involvement	Freedom	Trust/Openness	Idea-Time	Playfulness /Humor	Conflict	Idea-Support	Debate	Risk-Taking
1	86	200	180	133	167	100	180	167	120
2	171	67	240	67	117	67	140	167	80
3	71	33	20	83	17	250	120	200	100
4	129	150	100	117	117	83	220	183	100
5	286	183	300	250	217	33	280	233	200
6	229	200	220	217	167	200	220	217	180
7	186	233	240	250	200	217	260	167	180
8	214	167	280	233	167	250	200	233	220
9	214	183	160	200	217	167	200	217	160
10	200	250	200	217	250	200	220	250	240
11	200	133	200	50	50	83	120	267	60
12	214	133	160	100	133	83	300	267	100
13	286	233	100	150	133	233	220	267	240
14	143	150	160	150	83	200	120	117	100
15	171	217	120	167	133	217	180	183	160
16	214	217	220	200	217	183	200	183	160
17	214	200	240	217	200	217	240	233	160
18	200	200	220	217	200	200	220	217	140
19	214	233	240	183	267	217	160	183	180
20	243	183	220	217	217	233	220	250	200

Dimension / Respondents	Challenge/Involvement	Freedom	Trust/Openness	Idea-Time	Playfulness /Humor	Conflict	Idea-Support	Debate	Risk-Taking
21	186	167	200	200	217	200	180	250	220
22	171	150	200	217	183	233	220	250	200
23	286	150	280	133	167	0	280	200	100
24	271	233	160	200	167	133	240	200	160
25	286	217	140	250	150	100	240	250	140
26	14	33	0	0	17	67	0	33	0
27	243	167	160	183	183	100	280	200	120
28	171	133	80	133	100	67	160	133	60
29	143	117	100	133	117	133	160	183	100
30	271	283	300	250	183	17	220	250	140
31	186	117	120	100	100	100	140	183	100
32	186	150	160	100	183	283	160	200	180
33	200	133	180	100	117	67	200	217	140
34	257	200	220	233	100	100	280	250	160
35	229	183	200	200	200	150	260	233	160
36	243	183	160	200	150	83	200	183	160
37	157	117	100	183	150	67	180	167	120
38	200	200	180	150	100	83	260	200	160
39	157	117	120	133	100	117	160	200	200
40	186	133	240	133	167	50	160	283	140
41	186	217	180	250	233	183	240	300	240
42	271	200	160	200	200	50	200	250	200

Table 2. Means and Standard Deviations of the Technological Innovation Climate Dimensions

N◦	Dimentions	N	Mean	Std. Deviation
1	Challenge &Involvement	42	199.66	58.476
2	Freedom	42	170.63	53.951
3	Trust & Openness	42	177.62	67.311

N°	Dimentions	N	Mean	Std. Deviation
4	Idea Time	42	169.05	61.107
5	Playfulness and Humor	42	155.95	57.948
6	Conflict	42	138.49	75.033
7	Idea Support	42	200.95	57.075
8	Debate	42	209.92	48.704
9	Risk-taking	42	149.52	53.051

N= number of respondents.

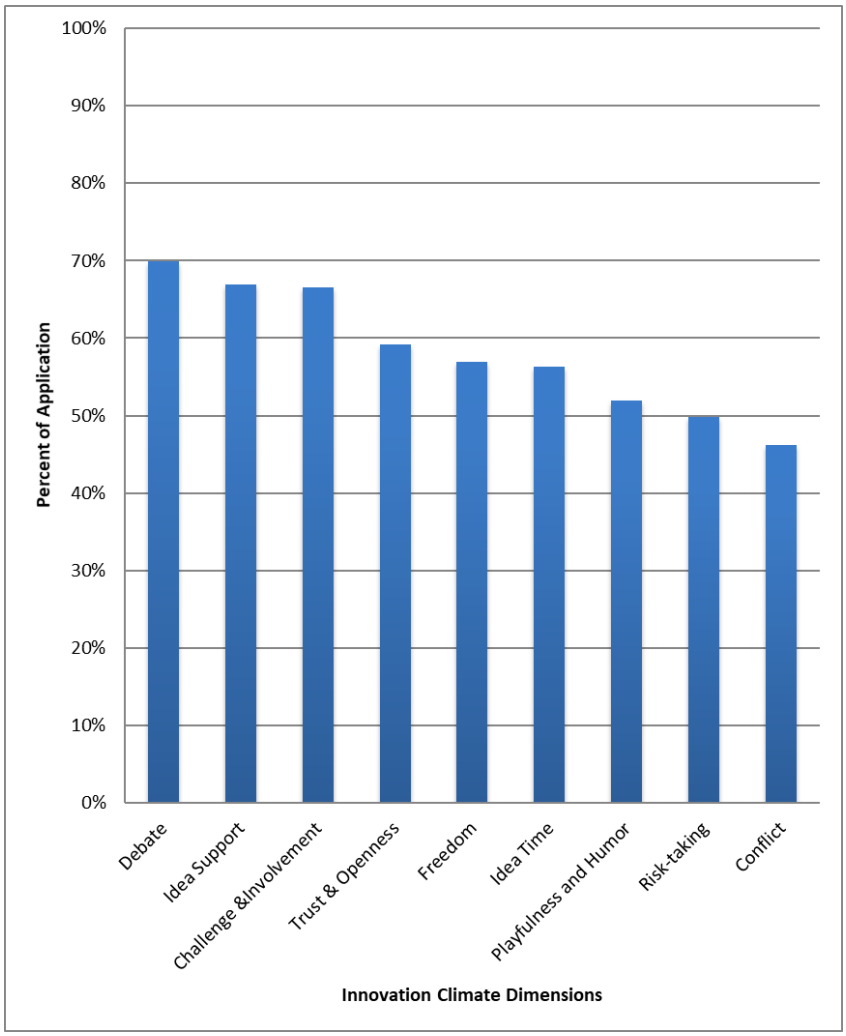


Fig. 1. Application levels of the technological innovation climate dimensions

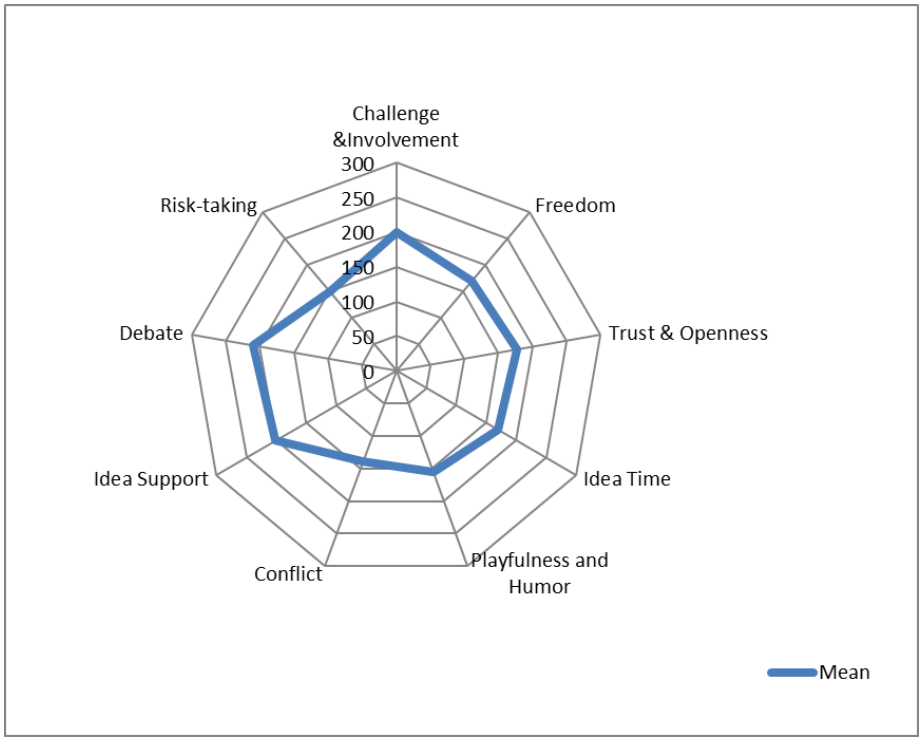


Fig. 2. Assessment of the company's innovation climate

6 Results, Analysis and Discussion

6.1 Debate

Debate means the occurrence and open disagreement between viewpoints, ideas, experiences and knowledge. In the debating situation, many different voices and points of view are exchanged and encouraged. In short it is the exchange of viewpoints, ideas, experiences and knowledge openly. Debate reflects a more productive climate as many voices are heard and people are keen on putting forward their ideas. The main characteristics of debate are: focuses on issues and ideas not on people and their relationships; involves the productive use and respect for diversity of perspectives and points of view; involves encounters, exchanges or clashes among viewpoints, ideas and differing experiences and knowledge. The results showed that the debate dimension obtained the highest score in the company's innovation climate and is applied with 70%. This indicated that the respondents discuss effectively with diversity and sharing opinion in positive ways. However, the dimension could reach the very high position. The consensus opinion of the participants showed that when the score on the debate dimension is too low: employees follow authoritarian patterns without questioning, and they constantly complain about the way things are rather than how they can improve the situation. However, the participants also conceded that if the open debate

is too high it is likely to exercise one or more of the following: employees focusing more on their individual goals and ignoring the company's goals; more talking than working.

6.2 Idea Support

Idea support is the way the new ideas are handled, treated and implemented. The way the new ideas are supported and treated will determine the assessment of better or worse the climate for creativity and innovation. The results revealed that the idea support is applied in the company with 67%. When the participants were asked: what is your understanding of a high idea-support? The opinion of the participants showed that their understanding of a high idea-support include the process used to get the ideas implemented is short and effective; employees listen open-handedly and generously to each other; employees give and take ideas, propositions and proposals in a focused and proficient manner; employees are satisfied with their jobs. When the participants were asked: what happens if there is insufficient support for new ideas? The opinion of the participants showed that in this situation the new ideas offered are few and most of them are outside the directions of the company; few ideas are accepted, and very few are implemented. As for the employees in a low idea-support situation the participants agreed that they would be: irritated by the tedious and mind-numbing process used to get ideas to action; frustrated because nothing is getting done; and dissatisfied with their dull jobs.

6.3 Challenge / Involvement

Challenge / involvement could be defined as "the level to which employees are not only involved in the organization's everyday operations but also in the organization's long-term goals". More involvement of the employees in the organization's vision, mission, goals, and everyday operations will enhance the climate for creativity and technological innovation. High levels of challenge & involvement means that: employees find enjoyment and importance in their work, and therefore they devote more energy in their work; employees are inspired and dedicated to contribute to the success of the organization; and the organization's climate has a dynamic, creative and inspiring quality. The results revealed that the application of challenge and involvement in the company is 67%. When the participants were asked: what happens when the challenge and involvement is too low? The opinion of the participants showed that in the situation when challenge and involvement are too low: employees feel alienated and dissatisfied with their jobs; employees general attitude is redundancy, dismissal, and unimportance in work; employees are neither engaged in the organization's everyday operations nor in the organization's long-term goals; employees interactions are boring; employees general attitude is redundancy, dismissal, and unimportance in work; employees often irritated about the future of their organization; and employees general attitude is redundancy, dismissal, and unimportance in work.

6.4 Trust and openness

Trust and openness among the organization's employees are how they openly communicate and trust each other. Trust and openness refer to the passionate and emotional security in relationships and interactions. These relationships and

interactions are considered safe and secure when employees are seen as not only proficient but also sharing a positive set of values. Trust and openness are often associated with employees having high level of independence and autonomy. Trust is the results of individuals' own personality, experience and organizational climate. The results showed that trust and openness is applied in the company with 59%. The consensus opinion of the participants revealed that low level of trust and openness results in distrust and suspicion, and means that employees are not communicating openly. When trust and openness are too low the creative climate becomes even worst. Employees keep information to themselves behind closed doors; if they have new ideas they fear of having them pinched; their feedback on other employees' new ideas, if any, is minimal and insignificant if any at all. The top and middle management of the organization have a tendency to unfairly allocate organisation's resources among sectors, departments, sections, groups and individuals.

6.5 Freedom

In general, freedom in the work environment is the level of independence shown by the employees in the organization. In more details, freedom could be described as the independence in the behavior, activities and actions exercised or utilized by the employees in the organization. High level of freedom implies more perceived autonomy and ability for individual discretion. To make better climate employees need to control over one's work and how to do it. The analysis of the respondents' results showed that freedom is applied with 57% in the company. The consensus opinion of the participants showed that, in general, strict regulations, procedures, guidelines and roles affect the climate of creativity and innovation in a negative way. Their opinions also showed that the main characteristics of a climate with high level of freedom are: employees are given autonomy in much of their work; they take the initiative to obtain and share data and information, they take decisions about their jobs; they exercise discretion in their daily actions and activities. The participants also revealed that the main characteristics of a work climate with little level of freedom are: employees show very little creativity for proposing better ways of doing their work; they focus too much on the requirements of what they are told to do; employees carry out their work in an officially prescribed methods, they perform all their work within strict role and procedures; and they spend exceptionally long time obtaining permissions, authorizations, and approval. In the work climate with low level of freedom the management style is usually authoritarian and/or bureaucratic. The participants also expressed their concerns about the work climate with too much freedom. Their perception of a climate with too much freedom is characterized by: employees' behavior and actions show no concern to the organization's strategy; and they are not concerned about their organization, they are mainly concerned about themselves.

6.6 Idea time

Idea time is the amount of time that is given by the organization to the employees to be used to generate and test new ideas. The concept is that giving the opportunity to stop work in order to generate and test new ideas will result in better innovation climate. Analysis of the results of the respondents showed that the idea time is applied in their company with 56%. When the participants were asked: what happens if there is

sufficient time and space for generating new ideas? The opinion of the participants showed that when the idea time is high new suggestions that are based on creative ideas are discussed and tested and employees are likely to use these suggestions. When the participants were asked: what happens if there is insufficient time and space for generating new ideas? The participants also stressed that individuals under time pressure are considerably less likely to be creative or innovative. The opinion of the participants revealed that when idea time is low the employees working hour is full and this causes time pressure which makes thinking outside the instructions and routines very difficult. Furthermore, the answers of the participants also revealed that in these situation employees are only concerned with their current tasks; they show an unhealthy level of stress; they see professional development and training as interruptions and hinders to their ability to compete their daily tasks. As for management, they avoid new ideas because they will take time away from the employees with the impact on the completion of their day-to-day work schedules.

6.7 Playfulness and humor

Playfulness and humor are when employees have a sense of humor and fun. Low level of fun at work reflect worst climate of creativity and innovation. More relaxed life where jokes and laughter occur often is enhancing the climate of creativity and innovation. The respondents revealed that the playfulness and humor dimension is applicable with 52% in their company.

6.8 Risk taking

Risk taking is meant to be the level of tolerance of uncertainty and ambiguity in the workplace. Both individual characteristics and organizational climate influence perceptions of risk and the tendencies to avoid, accept or seek risks. This dimension had the minimum score among all the nine dimensions of innovation climate with a percentage of application of 50%. This reflects the respondents' tendency to avoid failure and loss of financial and other resources. The opinion of the participants showed that when risk taking is too low: there is a general culture of caution, carefulness and hesitant mentality. The dominant behaviour of employees is to be on the "safe side"; this is often done by setting up committees and by covering themselves in many ways before making a decision. In general, employees complain about boring, low-energy jobs and are frustrated by a long, tedious process used to get ideas into action. The inevitable consequences of this behaviour are that employees offering very few ideas that are outside of what is considered safe. On the other hand, the consensus opinion of the participants revealed that in a high risk-taking climate: employees can take new initiatives when the outcomes are not completely known or certain; employees can take decisions even when they do not have full information. However, the participants revealed that if there is too much risk taking: the general feeling in the organisation's climate is that there are too many ideas floating around but few are approved and almost nothing is done; individuals do not feel they need a buy-in from others on their team and therefore there is no teamwork and the work climate is dominated by many loners doing their own things.

6.9 Conflict

Conflicts in an organization refer to the presence of personal, interpersonal or emotional tensions. All organizations have some level of personal tension. Conflict is a negative dimension; high score in the conflict dimension means high personal and emotional tension. According to Tidd & Bessant (2013) conflicts can occur over: tasks, processes or relationships. Task conflicts focus on disagreements about the goals and contents of work, the "what" needs to be done? And "why" to be done? Process conflicts are around "how" to achieve a task? Relationship conflicts are more emotional; they are characterized by hostility and anger and are generally energy-sapping and destructive. They also stated that some task and process conflicts are constructive; they might help to avoid groupthink, consider more diverse opinions and alternative strategies. However, task and process conflict only have a positive effect on performance in a climate of openness and collaborative communication, otherwise it can degenerate into relationship conflict or avoidance. The respondents' results reflected that there is a conflict in their work environment with 46%. When the participants were asked: what is the most important one factor contributing to the creation of a very high level of conflict in the work environment and the creative climate? The opinion of the participants revealed that when a very high level of conflict exists too many incompetent employees are rooted in an exceptionally high hierarchical organizational structure. Their incompetence coupled with their strong desire to keep their undeserved positions makes them create, generate, cause and implement a deliberate conflict climate in order to survive. The opinion of the participants also showed that the characteristics of the climate when the level of conflict is too high are: the work climate is characterized by open aggression, plots and traps, information hoarding, the general climate is dominant by groups and individuals that dislike each other, and even character assassination are not uncommon in the life of the organisation with too high level of conflicts. When the participants were asked: what are the characteristics of the work environment and creative climate when the level of conflict is too low? The opinion of the participants showed that when the level of conflict is too low: the work climate is usually characterized by individuals who lack any signs of creativeness, inspiration or encouragement; employees are not fascinated in or attracted to their jobs; management style is more about "telling" not participating or even selling.

7 Comparing the Company Results with International Norms

Comparing the result of innovation climate assessment with a benchmark or international norms will provide better understanding of the organization's ability and situation. Isaksen and Tidd (2006) published scores for the nine dimensions of innovative climate that are assessed by the SOQ and represent innovative, average and stagnated organizations. They explained that organizations were categorized as innovative, average, and stagnated based on their product performance and commercial success. Innovative organizations developed more new products and services, moved them to the marketplace quickly, and commercially successful overall. Stagnated organizations were unable to control development of new products and services, had difficulty getting them to market in a timely and cost-effective manner, and

commercially in trouble. Average companies fell in the middle. Several previous studies in innovation climate (Bakkar, 2003; Parrish, 2004; Senekal, 2007) have used the international norms from Creative Problem Solving Group to compare the results of their studies.

Table (4) shows the results of the innovation climate dimensions of the Saudi company together with the international innovative, average and stagnated organizations. The results, as illustrated in Figure (3) show that the Saudi company has better scores than the innovative organization in three dimensions: idea time, idea support and debate; and is equal to innovative organizations in one dimension, the trust / openness dimension. The results also revealed that the Saudi company is more than the average organizations and less than the innovative organizations in two dimensions, the challenge / involvement and risk taking dimensions. Also the Saudi company is less than the average organizations in the three dimensions of: freedom, playfulness / humor, and conflict. It can therefore, be concluded that the Saudi company could be categorized as an innovative company in the four dimensions of: idea time, idea support, trust / openness and debate. It could be categorized as average innovative company in the two climate dimensions of challenge / involvement and risk taking. However, the company is categorized as stagnated company in the dimensions of freedom, playfulness / humor and conflict; these results are illustrated in Table (5).

Table 4. Means of International Organizations Innovation Climate Dimensions and the Saudi company

Innovative Climate Dimensions	**Innovative**	**Average**	**Stagnated**	**Saudi Co.**
Challenge & Involvement	238	190	163	199.66
Freedom	210	174	153	170.63
Trust & Openness	178	160	128	177.62
Idea Time	148	111	97	169.05
Playfulness and Humor	230	169	140	155.95
Conflict	78	88	140	138.49
Idea Support	183	164	108	200.95
Debate	158	128	105	209.92
Risk-taking	195	112	53	149.52

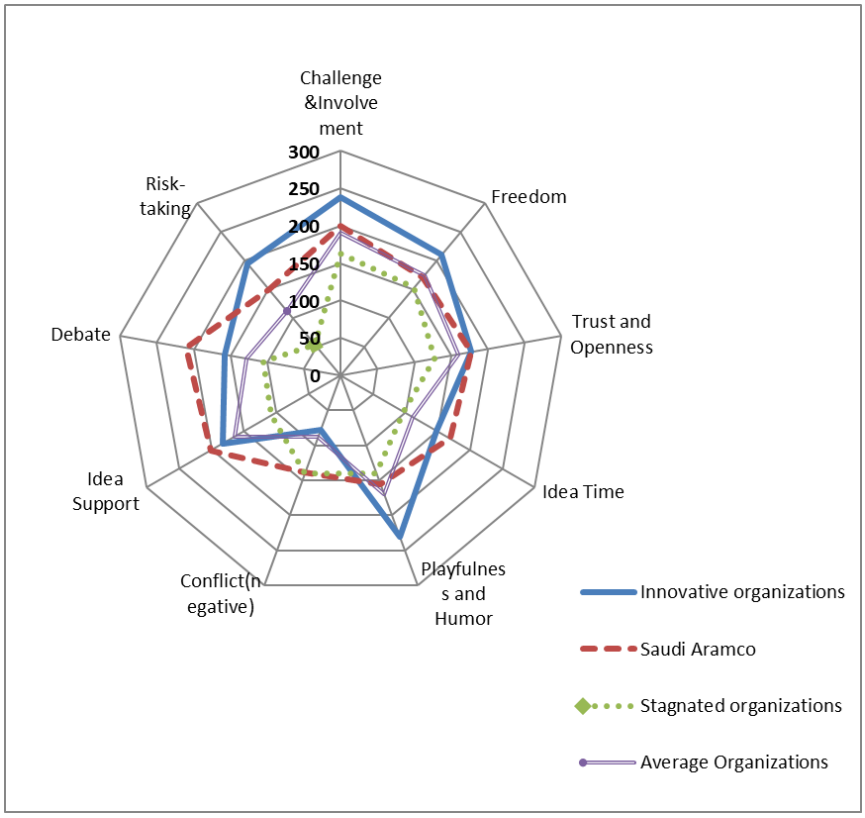


Fig. 3. The company innovation dimensions compared with the innovative, average and stagnated organizations

Table 5. The assessment results in relation to the three categories: innovative, average and stagnated organizations

Category / Dimensions	**Innovative**		**Average**		**Stagnated**	
	Better than innovative	Same as innovative	Better than average	Same as Average	Better than stagnated	Stag-nated
Challenge/ Involvement			*			
Freedom					*	
Trust/ Openness		*				
Idea Time	*					
Playfulness / Humor					*	
Conflict (negative)					*	
Idea Support	*					
Debate	*					
Risk-taking			*			
Total of the sub categories	3	1	2		3	
Category Total	**4**		**2**		**3**	

8 Strengths and Weaknesses of the Company in Relation to International Norms

To statistically test the strengths and weaknesses of the innovation climate of the Saudi company a one-sample t test is conducted to find statistically the significant deference between the Saudi company and the innovative organizations, and the significant deference between the Saudi company and the stagnated organizations. The t-test is used to determine if two sets of means are significantly different from each other (Rosenthal, 2011). The one sample t-test is used because the populations of the innovative and stagnated organizations are not available. When the difference is reliable or real it means significant difference between the Saudi company and the international innovative organizations in their innovation climate at the 0.01 level of alpha. The lower the value of alpha it is claimed that the result is statistically significant. If the dimension score of the Saudi company is statically equal or higher than the innovative dimension score, this is considered as strength point and if it is less or equal to a stagnated dimension score, this is considered as weakness.

8.1 Comparing the company with innovative organizations

Table 6 shows the means of the nine dimensions of innovation climate of the company compared with the values of innovative organization using t-test at level of p=.01

Table 6. T-test values of comparing means of innovation climate dimensions between the company and the innovative organizations

Innovation climate dimensions	Innovative organizations		
	T test	Df	*P*
Challenge / involvement	-4.249	41	0
Freedom	-4.729	41	0
Trust / openness	-0.037	41	0.971
Idea time	2.232	41	0.031
Playfulness / humor	-8.281	41	0
Conflict	5.225	41	0
Idea support	2.038	41	0.048
Debate	6.909	41	0
Risk taking	-5.555	41	0

P<0.01

The results showed that the company is significantly less than the values of innovative organizations in four dimensions: challenge / involvement, freedom, playfulness / humor, and risk taking. The results also showed that there was no significant difference between the company and innovative organizations in the three dimensions of: idea time, idea support, and trust / openness. This means that the company's levels are similar to the innovative organizations in theses dimensions. The main results from the t-test could be summarized in three points. a) The company's strongest innovation climate dimension is debate because it is significantly higher than innovative organization. b) It has three strong dimensions: idea time, idea support, and trust/openness because there are no statically significant differences between them and those of the innovative organizations. c) The remaining dimensions of challenge / involvement, freedom, playfulness/humor and risk taking are significantly less than innovative organizations, but still higher than the stagnated organizations.

8.2 Comparing the company with stagnated organizations

The means of each of the dimensions of the technological innovation climate in the Saudi company is compared with the innovation climate values of stagnated organizations using a one-sample t-test. The results are shown in Table (7), which shows that the means of the Saudi company are significantly higher than the stagnated organizations at level of p< 0.01 in the six dimensions of: challenge / involvement, trust / openness, idea time, idea support, debate, and risk taking. This means that the

company is significant higher than stagnated organizations in these dimensions. Whereas, there is no significant difference between the Saudi company and the stagnated organizations in the three dimensions of: freedom, playfulness / humor, and conflict. This means that the company and the stagnated organizations are similar in these dimensions. Therefore, the main results from comparing the company with stagnated organizations using the t test showed that the Saudi company weaknesses in the innovation climate dimensions are freedom, playfulness / humor, and conflict because there is no significant difference between the Saudi company and the stagnated organizations.

Table 7. T test values of comparing means of innovation climate dimensions between the company and the stagnated organizations

Innovation climate dimensions	**Stagnated organization**		
	T test	**df**	**P**
Challenge & involvement	4.063	41	0
Freedom	2.118	41	0.04
Trust & openness	4.777	41	0
Idea time	7.641	41	0
Playfulness & humor	1.784	41	0.082
Conflict	-1.13	41	0.897
Idea support	10.554	41	0
Debate	13.961	41	0
Risk taking	11.791	41	0

P<0.01

From the above results of the two t-tests, it could be concluded that the debate dimension is ranked higher than the innovative organizations and hence its measured level is considered too high. The dimensions of idea time, idea support, and trust / openness are considered as strong dimensions as their scoring are in the range of at the same level as the innovative organizations. While the innovation climate dimensions of freedom, playfulness / humor, and conflict are considered as weak dimensions as they are at the same level of stagnated organizations. The remaining dimensions of challenge / involvement and risk taking are considered as average strength dimensions. Table (8) summarizes the strengths, average and weaknesses of the technological innovation climate dimensions of the company.

Table 8. Strengths and weaknesses of the company's technological innovation climate

Too high Dimensions	Strong dimensions	Average Dimensions	Weak dimensions
Debate	Idea time Idea support Trust and openness	Challenge and involvement Risk taking	Freedom Playfulness and humor Conflict

9 Recommendations

a) Two main recommendations to improve technological innovation climate in the company were concluded from the results. First, maintain and sustain the strong dimensions of innovation climate in the company; these are: idea time, idea support and trust/openness. Second, focus to improve the three weak dimensions of freedom, playfulness/humor and conflict; focus to improve the too high dimension of debate; and improve the average dimensions of challenge / involvement and risk taking.

b) Recommendations to improve the too high dimension of debate: In this situation where the debate dimension is too high or at least almost reaching the "too high" position, and in order to keep it high but not too high, the participants recommended to hold structured discussions and affirm commonly held values among employees; and to get the employees involved in interpreting the vision, mission, purpose and goals of the organization.

c) Recommendation to improve challenge / involvement: To improve this situation, the participants recommended getting employees involved in creating or interpreting the vision, mission, objectives, and strategy of the organization. They also expressed that organizations that focus on work challenge rather than formal authority result in creative and innovative climate and organisation systems that provide useful information for subordinates to improve, learn and develop, results in higher levels of creativity and innovations.

d) Recommendation to improve risk taking: The participants recommended the development and continuous improvement of the reward, incentive, bonus, and promotion systems to encourage cooperation and integration rather than individualism and competition; and the structured formal efforts to help the development of team building.

e) Recommendation to improve conflict: To improve this situation, the participants recommended to scrutinize the organisational structure, identify leaders and high positioned employees who possess the kinds of competencies and qualities that fit the positions requirements, and replace those who do not possess these competencies and qualities. However, the participants recommended that cautious must be taken in order to keep the conflict level in the high level and not to keep reducing it to the low or the too low levels. Therefore, initiative to stimulate and provoke cooperation and integration among key individuals and departments in the organisation must be taken.

10 Conclusions

The Situational Outlook Questionnaire was used to assess nine key dimensions of the technological innovation climate in a Saudi company, one of the largest Oil and Gas companies in the Middle East. The results showed that the extent to which each of the nine dimensions is applied were: debate (70%); idea support (67%); challenge/involvement (67%); Trust and openness (59%); freedom (57%); idea time (56%); playfulness/humor (52%); risk taking (50%) and conflict (46%).

The results of the company were compared with published norms of international organizations. The climate of the Saudi company was categorized as innovative in the four dimensions of idea time, idea support, trust and openness, and debate; categorized as average innovative in the two dimensions of challenge and involvement, and risk taking; and categorized as stagnated company in the three dimensions of freedom, playfulness and humor, and conflict.

The above results were tested using the t-test and the results confirmed that the strengths of the innovation climate of the Saudi company are in the dimensions of: debate, idea time, idea support, and trust/openness. The weaknesses are in the dimensions of freedom, playfulness/humor and conflict.

The recommendations to improve technological innovation climate in the company were concluded from the results. Maintain and sustain the strongest dimensions of innovation climate in the Saudi company: debate, idea time, idea support and trust/openness. Improve the average dimensions of: challenge / involvement and risk taking. Focus to improve the weak dimensions of in the company: freedom, playfulness/humor and conflict.

Acknowledgments. The authors would like to thank the Creative Problem Solving Group, Inc. for allowing them to use the SOQ, to thank the reviewers for their valuable comments and the JIM founding editor for his support and cooperation.

11 References

Abdel-Razek, R.H. & Alsanad, D.S. (2014). "Auditing and comparing innovation management in organizations", *Global Journal of Business Research*, the Institute of Business and Finance Research, 8 (3), 49-56.

Abdel-Razek, R.H. (2014). *"A proposed framework for mapping technological innovation"*, Proceedings of the 2014 International Symposium on Business and Management - Fall Session, 12-14 November, 2014, Mejei University, Tokyo, Japan, pp. 377-389.

Abdel-Razek, R.H. & Alsanad, D.S. (2015). "Evaluation of innovation management in developing countries: a comparative study", *Arab Gulf Journal of Scientific Research (AGJSR),* Arabian Gulf University, 33 (1), 1-10.

Adolfsson, J., Stojcevski, T., & Lamskemper, J. (2013). *Influence Of Leadership Characteristics On Creative Climate In Research And Development Teams,* unpublished executive MBA thesis, Gothenburg University, Sweden.

Alabbas, S., & Abdel-Razek, R.H. (2016). "Mapping and benchmarking technological

innovation of three international petrochemical companies", *Journal of Innovation Management (JIM),* 4 (3), 101-124.

Alsanad, D.S., & Abdel-Razek, R.H. (2016). "Mapping technological innovation: methodology and implementation", *Journal of Review of Business & Finance Studies, IBFR*, 7(1), 59-67.

Amabile, T., Burnside, R. M., & Gryskiewicz, S. S. (1999). *User's Manual for KEYS, Assessing the Climate for Creativity: A Survey from the Center for Creative Leadership,* Center for Creative Leadership.

Anderson, N., & West, M. A. (1996). The team climate inventory: development of the TCI and its applications in team building for innovativeness. *European Journal of work and organizational psychology*, 5(1), 53-66.

Bakkar, A. A. (2003). *Creativity-Enhancement In Media Organizations: A Study Of The Perception Of Journalists And Media Managers In Saudi Arabia,* unpublished Ph.D. dissertation, University of Oklahoma Graduate College.

Hoe, S. (2011). Measuring an organization's innovation climate: A case study from Singapore. *Development and Learning in Organizations*, (25) 6, 1-10.

Hunter, K. Bedel L., & Mumford, M. (2005). Dimensions of creative climate: a general taxonomy, *The Korean Journal of Thinking and Problem Solving*, (15) 2, 97-116.

Hunter, S. T., Bedell, K. E., Mumford, M. D. (2007), Climate for creativity: A quantitative review, *Creativity Research Journal*, 19, 69-90.

Isaksen, S. G., Lauer, K. J., & Ekvall, G. (1999). Situational outlook questionnaire: A measure of the climate for creativity and change, *Psychological Reports*, 85(2), 665-674.

Isaksen, S., & Tidd, J. (2006). *Meeting The Innovation Challenge: Leadership For Transformation And Growth*. John Wiley & Sons.

Isaksen, S. G., Ekvall, G. (2013). *Psychometrics Of The Current Version Of The Situational Outlook Questionnaire: A Technical Resource For The SOQ*. Buffalo, NY: Creative Problem Solving Group – Buffalo.

McAlindon, H. R. (2004). Innovation Climate, *Information Technology Leadership in Higher Education*, (1), pp.73-82.

Mathisen, G. E., & Einarsen, S. (2004). A review of instruments assessing creative and innovative environments within organizations, *Creativity Research Journal*, *16*(1), 119-140.

Parrish, E. L. (2004). *A Comparative Study Of The Organizational Climate At The Army Materiel Command Regarding Creativity And Change*. Unpublished Ph.D. dissertation, Minneapolis, MN: North Central University.

Parther, C. (2010). *Managers Guide to Fostering Innovation and Creativity in Teams*. Madison, Wisconsin: CWL Publishing Enterprises developed for McGraw Hill.

PriceWaterhouseCooper (2007). *Compete & Collaborate,* the 11th Annual Global CEO Survey, New York.

Rosenthal, J. A. (2011). *Statistics and Data Interpretation for Social Work*. Springer Publishing Company.

Sanyal, B.C., & Varghese, N.V. (2006). *Research Capacity of Higher Education Sector in Developing Countries*. International Institution for Educational Planning, UNESCO.

Siegel, S. M., & Kaemmerer, W. F. (1978). Measuring the perceived support for innovation in organizations, *Journal of Applied Psychology*, *63*(5), 553-563.

Senekal, E. (2007). *The influence of organizational climate on creativity and innovation in a technology firm in South Africa, unpublished* Master's thesis, Faculty of Management, the University of Johannesburg.

Tidd, J., & Bessant, J. (2013). *Managing Innovation: Integrating Technological, Market and Organizational Change*. John Wiley and Sons, Inc.

UNESCO. (2010). UNESCO Report. United Nations Educational, Scientific and Cultural Organization. Accessed 10th January, 2016 from: http://www.unesco.org/science/psd/publications/usr10_arab_states.pdf

JIM 5, 3 (2017) 55-74
HANDLE: http://hdl.handle.net/10216/107952
SM: Jul/2016 AM: Jul/2017

Motivation for increasing creativity, innovation and entrepreneurship. An experience from the classroom to business firms

Francisco G. Barroso-Tanoira

Faculty of Economics and Business Administration Anahuac Mayab University, Business Division, Mérida, Yucatán, México

francisco.barroso@anahuac.mx, fbarroso_tanoira@yahoo.com.mx

Abstract. This study presents a program for increasing students´ motivation to be creative, innovative and entrepreneurs, based on interventions in business firms for improving employee performance through the use of critical and creative thinking. Results showed that the program was effective both for workers and students, and that the most important factor to be considered for enhancing creativity, innovation and entrepreneurship is intrinsic motivation. People are more creative when they do what they like, instead of just doing what they know or what they are told to. The more creative people are, the better performance and higher productivity could be expected. This is an opportunity for educational institutions to set links with business firms and take a more active role in human and business development.

Keywords: Motivation; Business Management; Critical thinking; Creative thinking; Employee performance; Innovation; Entrepreneurship.

1 Introduction

In the early 2000´s, when I was a professor at a public university, I started the first day of my Organizational Behavior class with an activity for introducing ourselves. Every student was asked to say his name, place of residence and a goal in life (in this document, "he" and "his" also refer to "she" or "her"). The first one said his name, where he lived and that his goal in life was to get his major with a good grade. The second mentioned the same goal, and so the next one. When eight students mentioned the same goal, I decided to stop the activity and ask why they were repeating the same. Of course it is important to finish with a good grade, but it is more important to learn how to learn, solve problems and enjoy the learning (Peters, 2012). Besides, there are other goals in life like starting a business, getting an academic degree, joining a large and important enterprise and having a family, all within ethics and considering the human person in the center of any activity. Finally, a company must know when to reinvent, aligning everybody for a change before problems arise (Bertolini, Duncan & Waldeck, 2015).

What happened was not the students' blame. A study in Mexico City, reported by Olivares (2015), in which there´s a pre-college educational crisis that could be found in other parts of the Country, showed an insufficient level of achievement in the education stages before

ISSN 2183-0606
http://www.open-jim.org

going to the University. Such an academic environment is producing employees for serving the system instead of people with critical and creative thinking competencies, able to make decisions, solve problems and create value for the organization they will be part of. And this is the way in which the school system is in many countries in the world, wasting the creative and innovative potential students (and professors) already have.

Getting back to the experience I shared at the beginning, those students only repeated what they thought their world was: getting a better grade for being hired by someone else. Although it is not bad to be hired, the bad thing is thinking that being hired is the only way for working and making a living. At least 85% of them came from families in which their parents were employees, so entrepreneurship was not a family topic. That´s why it is important to foster criticism, creativity, innovation and entrepreneurship at all school levels, especially at the university. Both, the family environment and the school system, must be adequate for educating innovators and entrepreneurs.

Could we say that the best student is the one who gets the highest grades? Of course we can´t. A student who gets the highest grades is the one who answered everything his professor asked. But if the professor is outdated or if he is only an academic without links with the business environment, that highest mark could mean nothing in the real labor world. This means that it is important for all professors to get involved in projects and activities and be updated all the time, having in mind that educating is not filling the students' head with knowledge. It is more than that…educating is giving those students everything they need to be what they came to the world for. In other words, the challenge is educating leaders to change society in a positive way, centered in human values. It is our duty, as professors, to help our students to be better professionals, but above all, to be better people. This way some of them might be good employees and others good entrepreneurs. If a school fails to prepare students for life and just focus on traditional classes (teaching centered) instead of real education (learning centered), the damage to society could be immense.

1.1 Problem statement

Motivation, creativity, innovation, leadership and tolerance to risk are entrepreneurial competencies related to fostering entrepreneurship, improving performance and achieving sustainable development (Barroso, 2012; Salinas, 2014). In companies in the region, training efforts have been addressed to increase technical competencies (those directly related to what a person in a job is expected to do) and transverse ones (those all jobs have in common including socioemotional ones, like communication, leadership and others). However, According to Aceves & Barroso (2016), the two most important competencies to be strengthened at school beyond knowledge are conflict solving and decision making, which need critical and creative thinking to be achieved. Besides, there are students who think they are neither creative, nor innovative, and entrepreneurship is out of their scope. The result is loss of creative potential and money because of mistakes, routine, boredom and lack of opportunities for developing human capital.

Through training, business enterprises must help employees improve their competencies and use them at work (Barroso, 2012). However, an enterprise must be similar to a school, giving employees the chance to explore, learn and develop beyond the traditional mechanical work (Resnick, 2007). As education continues along life, enterprises must educate individuals to become better employees, as well as better citizens and family members.

A job is not only something a person does for getting money. It must also be an opportunity to get a better quality of work life. But as the employee was once at school, it is important to educate future professionals since they are at the kindergarten and especially at the university. An important way for learning about conflict solving and decision making is helping students to be more creative, which could be achieved through teaching critical and creative thinking strategies. How to do it in an environment in which students learn by doing and discover new things, also learning how to learn and enjoying the experience?

It is important that students realize the importance of being creative and fostering creativity at work, instead of thinking that creativity is a pretty but useless course, only good for artists or scientist. For teaching critical and creative thinking some professors use traditional methods based on theory, which could be all right for teaching knowledge, abilities or skills, but not effective for helping students to learn how to learn, or for improving their motivation to be creative, innovative and become entrepreneurs.

Learning in a traditional class could be boring and a waste of potential motivation for students to engage in their own learning, for which constructivist methods are more effective (Peters, 2012). On the other hand, it is necessary to have programs in which students learn from direct experiences in business firms, which also open opportunities for education institutions to have links and agreements with business firms, the Government and other academic organizations. To which extent could a program in which students enhance creativity in business firms, increase their own motivation to be creative, innovative and entrepreneurs? Does employee performance improve as a consequence of such a program?

1.2 Objective

Testing a program for increasing students´ motivation to be creative, innovative and entrepreneurs through interventions in business firms for improving workers' performance using critical and creative thinking.

Specific objectives:

- Identify the most important factors students must consider at designing an intervention for fostering creativity in business firms.
- Design activities to be included in the students' intervention program in business firms.
- Verify if there is significant difference in workers' creativity and performance as a result of the students' intervention.

- Verify if there is a significant difference in students' motivation to creativity, innovation and entrepreneurship as a result of their intervention in business firms.

1.3 Importance of the study

This research is important because of the opportunity students have for using what they have learned in the "Creativity and Innovation" course, in real work situations identifying a problem, designing and implementing an intervention plan in enterprises and measuring results. Students learn through helping others (employees in this case) to explore, discover, develop and learn from their own context. On the other hand, employees could improve their performance and enjoy their job more and increase enterprise profitability, which could be translated into better working conditions, more competitive salaries, as well as lower turnover and absenteeism. Another benefit is that directors and managers will understand the importance of an environment which fosters creativity, innovation and entrepreneurship. This time six business firms were directly benefitted and the results will be used in future class programs and case studies.

Everybody wins with this intervention: the student learns through a direct involvement with real situation problems; the firm improves creativity and employees´ satisfaction, and customers have the chance of getting better products and services. Besides, there could be a continuous opportunity for managers to improve performance through the help of students, which could strengthen the links between the university, the Government and business firms.

2 Literature review

2.1 Creativity, critical and creative thinking

Much has been said about creativity, its value for achieving competitiveness and face competition in this every day more complex and diverse world. To be competitive, firms need to solve their problems in an innovative way, with ideas that allow them to constantly adapt to their environment and survive. This means that creativity is a source of competitive advantage, this is, a source of differentiation in the long term or forever. However, although it is considered important, in many firms creativity is not enhanced or their directors think it is only for designers or the marketing staff (Barroso, 2012).

Creativity consists in generating new ideas and communicating them for creating value (De la Torre, 1997), or the capability for combining new and useful ideas, different to what has been done before, but appropriate to the problem or opportunity presented (Robbins & Judge, 2013). For Robinson (2006), creativity is generating new and different ideas with value, and must be at the same level as literacy because everybody is born with it, but we have to develop it as we grow up. All humans are creative and express their creativity, so it is inherent to all human activities.

Critical thinking is an intellectual activity aimed to question, analyze or assess the structure

and consistency of reasoning, especially those beliefs and affirmations that are normally considered true through knowledge and intelligence (Caroll, 2000), oriented to achieve a more reasoned and supported position about a topic. For the UMICH [University of Michigan] (2015), it is the process we use to reflect on, assess and judge the assumptions underlying our own and others ideas and efforts.

The term "critical" comes from "criticism", which comes from the Greek word "*krínein*", meaning to analyze, separate or discern. Then, critical thinking searches for clarity, accuracy, precision, evidence and equity, and for that there is an analytical and an evaluative line trying to give the individual the corresponding intellectual tools for distinguishing what is reasonable and what is not, or what is true and what is false. Fobler & LeBlanc (1995) suggest that ideas must not be accepted just as they come, and for Caroll (2000), they must be analyzed through observation, experience, reasoning and –if necessary and possible- using scientific methodology because the objective is going beyond subjective perspective, impressions and personal opinions.

The components of critical thinking are: (1) ideating and challenging assumptions; (2) recognizing the importance of the context; (3) imagining and exploring alternatives, and (4) develop reflective skepticism. Critical thinkers reorganize underlying assumptions, scrutinize arguments, judge ideas and the rationality of justifications comparing them to a range of varying interpretations and perspectives. According to Paul (UMICH, 2015), they achieve this through the following habits of the mind: confidence, contextual perspective, creativity, flexibility to adapt and change ideas or habits, inquisitive integrity, intuition, open mindedness and reflection

There are five phases of critical thinking (UMICH, 2015):

1) **Trigger event**: an unexpected happening is presented, creating surprise or discomfort
2) **Appraisal:** it is a period of self scrutinizing to identify and clarify the concern
3) **Exploration**: it is searching for ways to explain the circumstances
4) **Developing alternative perspectives**: it is selecting those assumptions and activities which seem the most satisfactory and congruent
5) **Integration:** becoming comfortable with, and acting on new ideas, assumptions and new ways of thinking

Critical thinkers must also develop the following skills, according to Scheffer & Rubenfeld (UMICH, 2015):

1) **Analyzing**: it is to separate or breaking a whole into parts to discover its nature, functions and the relationship among those parts
2) **Applying standards**: it refers to judge according to established rules or criteria
3) **Discriminating**: recognizing differences and similarities among concepts and things or situations. It is also distinguishing carefully categories and ranks
4) **Information seeking**: searching for evidence, facts or knowledge by identifying relevant sources. It is looking for relevant information.
5) **Logical reasoning**: drawing inferences or conclusions supported by evidence

6) **Predicting**: it is envisioning a plan and its consequences
7) **Transforming knowledge**: changing or converting the condition, nature, form or function of concepts among concepts.

There are different techniques for teaching critical thinking, such as mind maps, concept maps, synoptic charts, Ishikawa (fishbone) diagrams, Gantt charts and others, leading to discussions, synthesis and evaluations.

On the other hand, creative thinking is a way for looking at problems or situations from a different and fresh perspective, suggesting unorthodox situations (Businessdictionary, 2015). Creative thinking can be stimulated both by an unstructured process such as a general brainstorming session, and by a structured process such as lateral thinking. However, brainstorming is very structured when it is used as a method. According to UMICH (2015), creative thinkers consider rejecting standardized formats for problem solving, have an interest in a wide range of divergent fields, take multiple perspectives on a problem, use trial and error methods in their experimentation and are self confident. They trust their own judgement.

Creative thinkers keep track of their ideas, pose new questions and are open and receptive to new ideas, avoiding rigid and set patterns of doing things. They are updated in their fields to solve problems, read and look for the most important advances related to their activities, so they also use critical thinking techniques to process information. Engaging in creative hobbies, adopting a risk taking attitude and keeping up a good sense of humor are important aspects for being a creative thinking (UMICH, 2015).

For De la Torre (1997), the most important features for a person to be creative are: (1) sensitivity to problems, deficiencies, failure, gaps and improvements; (2) autonomy and criterion independence; (3) good self perception, (4) high level of expectations, and (5) engagement and consistency at work. Less creative individuals follow a strict plan, while more creative ones could change everything once again and again, planning solutions to problems from different points of view until they reach what they want. This means that, for being creative, there are three components needed (Robbins & Judge, 2013): (1) **competency**, which means knowledge plus abilities plus attitudes in their work field; (2) **creative thinking abilities**, such as intelligence, independence, risk taking, self-control, tolerance to ambiguity and avoiding frustration; and (3) **intrinsic motivation** in the assignments, which refers to interesting, intensive and emoting work.

Critical thinking could be related to the left side of the brain (De Bono, 1994; Senge, 1995) which is the vertical o rational thinking, while creative thinking is related to the right hemisphere, which stands for intuition, creativity and lateral thinking.

2.2 Creativity, innovation and entrepreneurship in business firms

Creativity is a social benefit because it helps the development of the individual within a human, scientific and cultural frame (De la Torre, 1997). For Clegg & Birch (2001), just a few business firms could survive without creativity in the market because the game today is constant change. The most evident value of creativity is that it helps those who make

decisions understand problems and see what others can´t.

As systems, business firms and other human organizations are linked through invisible connections that sometimes take years to arise and show the mutual benefits. When vision is shared, people improve performance because they want, not because they received an order to do it (Senge, 1995). That vision is usually spinning around the leader´s charisma or because of a crisis. Having a shared vision fosters creativity and, at the same time, that creativity strengthens the vision. Besides, in firms where creativity is enhanced there is less employee turnover and absenteeism, employees are more satisfied and the environment is much nicer (Barroso, 2012).

Fobler & LeBlanc (1995) suggest that, for enhancing creativity is important to implement the following, regardless the kind of organization:

a) Implement reverse thinking and enhance discussion.
b) Build a creativity inspiring environment. Nobody can buy creativity (Florida & Goodnight, 2005), but everybody could be inspired to be creative.
c) Include emotions in the system, so people get involved.
d) Create an environment in which participants are free of worries, take risks and are not afraid of making mistakes.
e) Avoid excess of safety because that can lead to conformism.
f) Set high performance standards
g) Motivate confidence on responsibility, but without being too concerned about rules.
h) Be sure people see the results of their work. Feedback is a must.
i) Try ordinary people achieve goals and do extraordinary things.

One common mistake, according to Gámez (1998) and Barroso (2012), is that creativity is usually related to tangible results. However, there are intangible ways to be creative, like creativity in ideas, the relation among workmates, improvisation, planning, leadership and personal organization. Besides, it is important to identify and eliminate barriers to creativity. For Hellriegel & Slocum (2004), they are:

a) Barriers to perception: not using all senses for problem solving; the difficulty for observing distant relations and not being able to distinguish between cause and effect.
b) Cultural barriers: the wish to adapt to established rules, avoid conflicts or an exaggerate focus on competition. It is also thinking that fantasy and other exploration actions are a waste of time.
c) Emotional barriers. They refer to the fear for making mistakes. They include not trusting others or accepting the first coming idea. For avoiding this, the best is enhancing lateral thinking (De Bono, 1996).

The driver for creativity is connectivity (Johnson, 2010). Hallman, according to Rivero (2002), suggests that connectivity is a necessary condition for defining and understanding creativity. Individuals now are better connected and have the possibility for developing creativity in a faster way than before. However, for preparing a learning plan for students, the features presented must take in mind the following: (a) learning activities; (b) Characteristics of the learner; (3) the nature of materials, and (5) the criterial task, which is the aim of the activity (Center for the Study of Reading, 1980).

For Barroso (2007), even when managers think their employees are creative, they don´t let them use their creativity, resulting in routine work and low motivation. Creativity is rewarded only with money (if it is rewarded) and there is limited use of creativity, but more use of power, rules and fear to change. As a result, there is fear to failure and avoidance for taking risks, which limits creativity and does not let it become innovation. Then, creativity is the foundation for innovation, which means that for being innovative, the first is being creative.

In business firms, at least in the Southeast of Mexico (Barroso, 2012), even when there are managers and directors who think their employees are creative, those employees have limited freedom to be creative and only tangible creativity is acknowledged. Power, rules, an unfavorable work environment or fear to change set limits to the employees, who perform more as executers than as thinkers. Gupta (2012) suggests that, for innovation, it is important that individuals master the following areas: (1) time management; (2) logic reasoning processes (process thinking); (3) statistic thinking, and (4) innovative thinking. Learning to innovate is not just accumulating knowledge, but getting the best of that knowledge. Then, the objective of education in innovation is preparing and empowering individuals for a faster innovation using creativity for giving value to the customer. To be significant, an innovation must be accepted by its users and be profitable. Of course, innovation could be measured with other indicators and metrics than monetary profits depending of what is innovated.

Managers acknowledge that it is necessary to have creative employees, but they are not properly prepared for this, thinking that technical competency training is enough. This training is focused on stimulating rational thinking teaching about techniques, procedures and norms. It is necessary to foster intuition through problem solving sessions using critical thinking techniques for organizing information (idea association, analogies), and creative thinking. Otherwise, employees' creative potential will be wasted. It's amazing to see that even though everybody in business firms think they know what creativity is and its importance, it is not enhanced and the human creative potential is not properly used.

Entrepreneurship is one of the main actors in national economy for any country (Salinas & Barroso, 2016). For Ahmad & Seymour (2008), there are some common elements that impulse people for entrepreneurship: (a) the capacity for finding and exploiting a business opportunity, and (b) intention to understand the entrepreneur´s behavior. Feldman & Bolino (2010), as well as Katz (2004), consider that the intention to become an entrepreneur depends in the individual´s will because people value the possible results, economic impact and community benefits. This could be motivated by two factors: (1) the environment, and

(2) sociodemographic and perception features. Drucker (2002) comments that successful entrepreneurs don´t wait for new and creative ideas to come. Would-be innovators and entrepreneurs must go out of the firm, look, ask and listen, in a process for exploring-discovering-learning process. Effective innovations start small and must be simple and focused, understanding the potential users' values and analyzing the information using both sides of the brain.

Family, personal economy and academic level also have influence in the process of entrepreneurship (Barroso, 2012; Salinas, 2014). Quijano (2006) agrees that productivity is affected by factors such as motivation, labor satisfaction, learning, academic level, work habits, labor environment, attitudes, feelings, decision making, conflict solution, ergonomics, management style, organizational culture. For Cequea, Rodriguez & Núñez (2011), there are four human factors that affect performance: (1) individual; (2) group; (3) organizational, and (4) productivity. Students learn better when they are provided with the proper training and have the correct assistance over the time (Min, 2005).

There are people who think they are not creative, but everybody is. Creativity is inherent to our nature and must be, as Robinson (2006) said, treated at the same level and importance as literacy. It has its own value, as De la Torre (1997) stated, but only when it creates value and becomes innovation (Gupta, 2012), so to be innovative, the first step is fostering creativity. And if there´s orientation to innovation, there will be the possibility for individuals to be entrepreneurs. We can say that the creator has an idea, the inventor makes it work, the innovator gives value to that idea and the entrepreneur takes the risk and takes it to the market, transformed into a product or service.

All those people working in business must be entrepreneurs because as the world is changing too fast, it is a deadly risk to remain doing the same. In this sense, organizations must be made to change, not simply to last, because if they adapt to change, they will last in the market as a result. So, sustainability must not be seen as an objective, but a result of constant change adaptation. Innovation and entrepreneurship aren´t activities…they are ways of being, ways of living. I would say they must become values included in the company philosophy.

All of the above could be applied to students' training for being prepared for work. As Aceves & Barroso (2016) mentioned, their success at work will be based in their socioemotional competencies, which sets the importance of leadership, teamwork, creative problem solving, communication, conflict solving and decision making. All of this need the use of creativity and critical thinking tools. The focus on work activities enhance skill improvement, confidence, build-up and metacognition (Min, 2005). For the Center for the Study of Reading (1980), feedback plays an important role in this training because students are more successful when they see the outcome of their actions and are instructed in self corrective procedures.

3 Methodology

The research was focused on the students. What they did in the firms, besides the benefits for the workers and the organization, was a mean for measuring the difference in students' motivation to creativity, innovation and entrepreneurship, so there was an intervention (workers' change) within another intervention (students´ change). The last one is the research object. The study is descriptive and because a comparison among groups of students was not possible because they intervened in different firms, the research had a pre-experimental design (Hernández, Fernández & Baptista, 2014), which means that the results of each group of students were compared before and after the intervention through a test-retest practice, without a control group.

3.1 Participants

The study was performed with students from an acknowledged private university with more than three thousand students and 32 years in the South East of Mexico, which is part of a university national system in Mexico. There were 38 students enrolled in this experience, all of them registered in the Creativity and Innovation course during the August-December semester in 2014. The average age was 19 years old, 24 of them women (63.2%). About their place of residence, eleven were foreign (four French, three Belgians, two Germans and two Dutch) who were in a student exchange program. Regarding the nationals, they were from the states of Yucatan, Campeche, Quintana Roo and Tabasco, in the South East of Mexico. This course is in the seventh semester according to the curricula, so the students are about to finish their studies. Twelve nationals are already working and studying, and all foreigners have work experience. The analysis unit was the whole group of 38 students, not the sub groups sent to each enterprise. The data was gathered in the August-December 2014 semester and reported in 2015.

3.2 Instruments

Questionnaire for employees Before the intervention, students applied the employees Part I of a questionnaire named ECQ (Employee´s Creativity Questionnaire), which I designed for this purpose. The concept of creativity was not previously explained to the workers because it was required to know what they knew about it. The first part is the following:

Part I. General idea about creativity (pretest and post-test for employees):

1. It´s difficult to be creative
2. Creativity is easy
3. Creativity is fun
4. I´m a creative person

At the end of the experience, students applied to workers Part I again (as a posttest), but also Part II:

Part II. Regarding this experience (only at the end of the intervention)

1. It helped me realize I´m creative
2. It helped me use my creativity
3. I enjoyed this experience
4. I´m fearless about having mistakes
5. I´m more creative now than before this activity

Content and construct validity (Hernández et al., 2014) was verified by three experts in methodology, motivation and creativity, all of them with several years of experience as academics and consultants. Construct validity was verified by those experts because there were just nine items, which are too few for a factor analysis. The constructs revised in Part I were the concept of creativity in item 1 (Robbins & Judge, 2013) and the features for a person to be creative in items 2 to 4 (De la Torre, 1997). In Part II, the constructs verified were the components of creativity in items 1 to 3 (Robbins & Judge, 2013), eliminating barriers to creativity in item 4 (Hellriegel & Slocum, 2004) and the results of creativity in item 5 (Gámez, 1998). For reliability, the questionnaire was applied to a random sample of 20 workers of different enterprises, with a resulting Cronbach´s alfa of 0.82 for Part I, 0.83 for part II, and 0.81 for the complete instrument, so it was considered reliable. At the end there was an open section in which employees were invited to write free comments about this experience.

CCTIE questionnaire for students A questionnaire for students, named "CCTIE" (Creativity, Critical Thinking, Innovation and Entrepreneurship) was created for this study, both for pre and posttest. It was built using the critical thinking concepts of Caroll (2000), Fobler & LeBlanc (1995) and UMICH (2005), as well as the creativity components of Robbins & Judge (2013): competency, creative thinking abilities and intrinsic motivation. There was a question asking for the relation of all this with performance. It was divided in two sections: Section I (items 1 to 10) was for verifying if the student knew the concepts of creativity. Section II (items 11 to 30) was for verifying students' motivation for fostering creativity, innovation and entrepreneurship, based on the motivation questionnaire named "EM1" ("Escala de Motivación 1" or "Motivation Scale 1") by Álvarez (2012), but adapted to student attitude to be creative, innovative and entrepreneur. The items were the following:

1. Everyone is creative
2. Creativity improves employee performance
3. Creativity leads to innovation
4. Creativity leads to entrepreneurship
5. A good environment fosters creativity
6. High standards motivate people to be creative
7. Feedback fosters creativity and innovation
8. The most important for creativity is knowledge
9. The most important for creativity is critical thinking abilities
10. The most important for creativity is intrinsic motivation of the employee
11. I am motivated by using my creativity in my activities
12. I use my creativity for reaching the goals I need to accomplish

13. I like projects in which I have to be creative
14. I think everyone must innovate in what they are doing
15. I do not stop until I accomplish what I have planned
16. I get motivated by challenges
17. I like things which require the maximum effort
18. When I work on a project I learn more
19. I am always aware of what I have to improve
20. I like searching for new ways of doing things
21. I like doing things without the need of someone giving orders
22. I am creative
23. I am innovative
24. I am entrepreneurship oriented
25. Critical thinking helps individuals to be more productive
26. Creative thinking helps individuals to be more productive
27. Individuals are more creative when they enjoy what they do
28. Leadership influences creativity
29. Leadership influences innovation
30. Leadership influences entrepreneurship

Content validity (Hernández et al., 2014) was verified by the same three experts who analyzed the ECQ questionnaire. When used as a pretest, construct validity was verified by factor analysis through the main components method and varimax rotation. The highest variances for factors related to creativity were Intrinsic motivation to be creative (29%); Importance of critical thinking (23%), Knowledge of what one´s doing (15%) and Having and environment to foster creativity, innovation and entrepreneurship (12%), all of them standing for 79% of the total variance. Stability using Cronbach´s alfa was 0.84 in Section I and 0.89 in Section II, with a total of 0.86, so the instrument was considered reliable and the pretest was accepted.

Both questionnaires were designed using a Likert scale: Totally agree (5) / Agree (4) / Indifferent (3) / Disagree (2), and Totally disagree (1). The scale for interpreting the numerical results was: 1 to 1.5= Totally disagree / 1.6 to 2.5= Disagree / 2.6 to 3.5= Indifferent / 3.6 to 4.5= Agree, and 4.6 to 5= Totally agree. Open answers were grouped by frequency of appearance, organized in key ideas and categories.

3.3 Procedure

In the Creativity and Innovation course, two months after it started and all the theory was studied, discussed and practiced in class, students were organized in teams of five to seven members according to their availability of time, including at least one foreign student in each team. Finally, there were six teams sent to the companies (two manufacturing and four commercial ones, all of them Small-Sized).

The students, according to the problem they detected in the companies, designed the activities to help employees develop critical and creative thinking competencies for improving their performance, become more motivated for detecting problems and solve them. In those courses the professor, the company managers and supervisors were present, and the employees were twenty as maximum in each business firm, divided in teams according to the activities. The program, designed by the author of this study, included the following steps:

1) Students answered the CCTIE questionnaire (students´ pretest)
2) Students interviewed the owner, director, manager or whoever responsible for searching problems related to lack of creativity, innovation orientation or entrepreneurship.
3) Students interviewed employees (in all the firm or just a department, depending on the firm´s approval) to know what they are doing and detect problems related to creativity, innovation or entrepreneurship.
4) Students applied participant employees the ECQ Part I questionnaire (employees' pretest)
5) With the result of steps 2 and 3, students designed an activity program for fostering creativity in the employees, lasting for the rest of the semester (a month minimum). It could be activities performed for some hours a week or maybe one activity in a moment and another at the end of the period. They must include in the program an explanation about what creativity is, myths, innovation, entrepreneurship, etc., as well as the program objective. The program learning activities could include creative games, dynamics and others, but not jeopardy or guessing meaning games since these activities do not foster group participation. Critical thinking strategies for handling, analyzing and reasoning must be also included.
6) At the end of the program they interviewed managers and employees again to verify if there was a change in what they were doing and if there was significant difference between their performance and other performance indicators related to the program.
7) Students applied employees the ECQ Part I (employees' posttest) and Part II questionnaire.
8) Students asked employees about innovative ideas to be implemented for improving their workplace, production or any other alternative, using what they learned in the program.
9) Students recorded all these experiences in an edited video and showed it in the final course exam day, in a maximum of 5-8 minutes per team, with some time for feedback and questions from the professor and their classmates. The film must have included at least the testimonies of three employees and their manager or supervisor. At the end of the presentation, the students shared their learnings from this experience with the rest of the class.
10) Students answered the CCTIE questionnaire again as a posttest at the end of the final presentation session (students' posttest).
11) Students were invited to go ahead and use the learnings from this experience.

The activities designed by students for workers included the following activities, also supervised by the author of this research:

1) **Prepare:** Every activity (class, session or workshop) for employees had a trigger activity (games, puzzles, cases, stories). The objective was breaking the ice and preparing employees for the activity.
2) **Understand**: There was a period for analyzing the concern, explore circumstances. Critical thinking techniques (mind maps, synoptic charts, fish bone diagrams, Gantt charts) were used for organizing and classifying information. The idea was developing the skills mentioned by Scheffer and Rubenfeld, also quoted by UMICH (2015). The objective was that employees could understand the context situation and identify a problem to be solved.
3) **Solve:** Then, there was the creative thinking phase, motivating employees to look for solutions from a different, open or unorthodox points of view through the features quoted by De la Torre (1997): (1) sensitivity to problems, deficiencies, failure, gaps and improvements; (2) autonomy and criterion independence; (3) good self-perception, (4) high level of expectations, and (5) engagement and consistency at work. Brainstorming was used and the information was analyzed and organized using critical thinking techniques, using the steps for enhancing creativity suggested by Fobler & LeBlanc (1995). The objective was to find a solution for the problem detected.
4) **Action:** Setting concrete action plans, indicators and procedures for monitoring the implementation process.
5) **Feedback**: Then, there was the feedback from the students to the employees about the process and the way in which those employees participated in the process.

One of the expected results was to enhance entrepreneurship in the employees, this is, to have initiative for taking action for improving business outcomes, based on the individual, group, organizational and performance factors, as suggested by Cequea et al. (2011).

4 Results

4.1 Employees' experience

The results were analyzed for all the workers as a whole and just to see if there was an improvement in their perception about creativity. In Part I of ECQ questionnaire, the pretest mean was 3.4 (Indifferent, SD=0.65) and the posttest was 3.9 (Agree, SD=0.79), which means that they didn´t think they were creative, but they actually are. In Part II of ECQ, employees rated 4.4 (agree, SD= 0.46). Both differences were significant at $p<0.05$. They totally agree that this experience helped them improving creativity and not to be afraid to make mistakes. Besides, there were some general comments written at the end of the ECQ questionnaire, ranked from most to least number of mentions:

1) Creativity really helps me be a better employee
2) Creativity makes me more valuable for my work
3) I didn´t know I was creative
4) Creativity is fun
5) Creativity helps me enjoy my job
6) We need a nicer environment to foster creativity
7) I wish we had these activities more often

There was an improvement in the employees' performance, observed in less absenteeism, more productivity and enthusiasm at work, according to supervisors' records. They also reported that there was a better environment, people were more participative at work and were looking for problems to solve. There was a sense of satisfaction in what they were doing. Of course, there was support from each business firm acknowledging (not necessarily with money) the employees for the job done, even when some employees said that the rewards were not as important as the challenge they were feeling.

4.2 Students' experience

For students, Section I of the CCTIE had a mean of 3.3 (indifferent, SD=1.12) vs. 4.6 (Totally agree, SD=0.57), which means that they are now more convinced that critical and creative thinking have a relation with employees' performance. For Section II, the mean was 4.6 (Totally agree, SD=0.87) vs. 4.9 (Totally agree, SD=0.53), both significant at $p<0.05$, which means that even though they were highly motivated for fostering creativity, innovation and entrepreneurship, now they are more motivated to do that. General comments students wrote were, ranked from mostly mentioned:

1) I enjoyed this activity very much
2) I didn´t believe how important it is to foster critical thinking and creativity
3) I´ll foster creativity when I get a job or have my company
4) Everybody is creative
5) Creativity helps make more money
6) Creative employees are very valuable. Firms shouldn´t let them go
7) Employees who can use and develop creativity stay longer in the job.
8) Creativity is the foundation of innovation and change
9) Creative employees are a source of competitive advantage

Students were greatly surprised to see that helping employees to organize information and be creative improved their performance at work. The organizational environment improved and there was a meaning for doing things and for attending work. It was rewarding for students to know that employees expected for their arrival and were willing to participate in the activities.

5 Discussion

The five most important features mentioned by De la Torre (1997) were found here in the program, starting with sensitivity to problems, deficiencies, failures, gaps and improvements. The program was effective in this, so it could be affirmed that people are more creative and productive when they discover a problem or situation which is interesting. In the experience presented, the students felt motivated because the intervention was a challenge for them and because of the results they saw in employees after the intervention, which showed significant difference in the results for workers after the intervention, compared with those before the study. There was engagement both for the students and employees, which means that academy and real life are two sides of the same coin, and that they must be in cooperation all the time. This was also mentioned by Clegg & Birch (2001).

As a finding, according to the factor analysis and the intervention results, the most important factors to be considered for fostering creativity are: (1) intrinsic motivation to be creative; (2) implementation of critical and creative thinking tools; (3) knowledge (intellectual capital), and (4) a good organizational environment for enhancing creativity. This matched the components of creativity presented by Robbins & Judge (2013), but in this research, the most important one was intrinsic motivation for being creative, so motivation comes first, as it was found both for workers and students in this research. It means that people are more creative when they do what they like, instead of just doing what they know, so the first thing to do for enhancing creativity is making work interesting, challenging and with a meaning. The heart comes first, then the brain, as we can say. In all this process, as the Center for the Study of Reading (1980) suggests, feedback must be constant.

Then, according to the results, the most important for preparing students to increase their motivation to foster creativity, innovation and entrepreneurship is intrinsic motivation and immediate feedback about his actions. This is also valid for workers in business firms and sets up the importance for managers to know their employees and become real drivers for creative and innovative behavior. The more creative workers are, the better performance and productivity they could be. And, regarding the students, the more involved they are in fostering creativity in workers, the more motivated they are for enhancing creativity, innovation and entrepreneurship. It is a virtuous cycle.

This experience shows that it is possible to link the academia and business firms in an effective way through students' interventions, so there is a huge possibility for universities to help business firms improve at the same time their students learn how to learn. This also shows that enhancing critical and creative thinking improves workers' learning and helps business results increase. Delegating and empowering are also important, so giving students and employees freedom worked very well, as it was seen in this study.

It was not expected to have such a good participation of business firms, but their owners and directors gave their support and employees did it very well. There was some resistance to change expected, but it was just a little and vanished in the first days. Another finding is

that even in those firms in which the results were not as good, compared to other ones, students were motivated because they got engaged in the intervention. The next steps could be to replicate the experience in other areas and orient management to enhance innovation, as Gupta (2012) suggests. This intervention proved to be good for helping students develop the socioemotional competencies, at is was suggested by Aceves & Barroso (2016), especially regarding conflict solving and decision making.

6 Conclusions

Business firms dedicate resources for training their employees, but such training in many cases is ineffective because it is only based in technical aspects, not in transverse competencies such as teamwork, communication, leadership and critical and creative thinking. Employees are trained as executors, not as problem solvers, so it is necessary to teach them how to think critically and creatively to be managers of their own learning. On the other hand, traditional courses train students just to be students, designing projects as assignments which are often out of reality and just for getting a grade. But when students' talent is challenged through interesting real world contexts, their motivation increases and help others to learn.

As the results showed in this study, there´s a positive and significant relation between the use of critical and creative thinking with performance, according to the testimony of managers. Besides, it was possible to increase students' motivation to be creative, innovative and entrepreneurs engaging them in meaningful real situations helping other people to be creative, so the Prepare-Understand-Solve-Action-Feedback intervention program was effective for this purpose, and also an opportunity for students to learn helping others to learn. So, an effective way to be creative is helping others to be creative, which means that the most creative people are those who help others to be creative. Creativity increases when it is shared and innovation is the result of that. This program is also a good example of how the universities and enterprises could be linked in a win-win relation. In this sense, this program is an innovation in student education.

Business firms must also consider training their workers to be critical and creative thinkers, for enhancing creativity and achieving innovation and entrepreneurship. They could do this hiring professional consultants or setting links with education institutions to benefit from the aid of professors and students. As creativity will also engage workers to participate and become more committed to the firm, it is important to eliminate perception barriers and implement constant training, but not only in the rational aspect.

Finally, as the first step to be creative is motivation, the starting point for a business leader is to inspire his staff to be creative, innovative and entrepreneurs. For this, a good start is educating the student to be an inspiring leader, not just a boss who prefers people to execute, helping the enterprise adapt to its environment, develop and last. Further studies will include replicating this study in other firms and contexts for longer periods in order to explore new links between universities and business results, as well as the effect of

leadership, creativity, innovation and entrepreneurship in employee productivity.

The results are valid only for the companies participating in the study, but the program could be used in other contexts with the corresponding adaptations. The most important barrier was persuading the owners or directors to let their employees participate, but when they saw the results, those barriers vanished. And because of the short time of this intervention it could be considered a pilot program, setting the foundation of future longer periods of study to see changes in attitudes and work habits.

7 References

Aceves, M.A. & Barroso, F. (2016). Competencias socioemocionales en las prácticas profesionales. Un estudio en la industria hotelera [Socioemotional Skills in Business Practice. A Study in the Hotel Industry]. *Educación y Ciencia*, 5(45), 34-49.

Ahmad, N. & Seymour, R. (2008). Defining entrepreneurial activity: definitions supporting frameworks for data collection. *OECD Statics working papers*, 1. Retrieved Feb 20, 2016 from http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=std/doc(2008)1

Álvarez, L. (2012). Escala de Motivación (EM1) en el modelo motivacional de McClelland [Motivation Scale (EM1) in McClelland´s Motivational Model]. *Redalyc Tesis Psicológica*, 7. 120-143. Bogotá Colombia.

Barroso, F. (2007). *La creatividad en las empresas: percepción y sugerencias para su aprovechamiento. Un estudio con directivos de empresas y trabajadores* [Creativity in enterprises: perception and suggestions for its use. A study with business directors and employees]. Proceedings of the XI International Congress of the Administrative Science Academy (ACACIA). Tlaquepaque, Jalisco, Mexico. May 23rd-25th.

Barroso, F. (2012). Factores y razones para desarrollar la creatividad en las empresas [Factors and reasons for developing creativity in enterprises. A study in the Southeast of Mexico] *Revista de Ciencias Sociales,* 18(3), 509-516.

Bertolini, M.; Duncan, D. & Waldeck, A. (2015, December). Knowing when to reinvent. *Harvard Business Review*. Retrieved April 12 from https://hbr.org/2015/12/knowing-when-to-reinvent

Businessdictionary (2015). Retrieved Feb 20, 2016 from http://www.businessdictionary.com/definition/creative-thinking.html

Caroll, R. T. (2000). *Becoming a Critical Thinker*. A Guide for the New Millennium. U.S.A.: Pearson Publishing.

Center for the study of reading (1980). Learning to learn: on training students to learn from experts. University of Chicago at Urbana-Champaign. Retrieved from https://www.ideals.illinois.edu/bitstream/handle/2142/17857/ctrstreadtechrepv01980i00189_opt.pdf?sequence=1&sa=U&ei=JSVXU9_9GqLT8AG4roC4Dw&ved=0CC

0QFjAE&usg=AFQjCNHNVAXFo_ujbffFonUgGxk_HeP17Q

Cequea, M.; Rodríguez, C. & Núñez, M. (2011). *Diseño de un instrumento para evaluar la productividad laboral en empresas del sector eléctrico venezolano* [Instrument Design for Evaluating Labor Productivity in the Venezuelan Electrical Sector Enterprises]. Proceedings of the XV International Conference on Industrial Engineering and Industrial Management.

Clegg, B. & Birch, P. (2001). *Creatividad al instante* [Instant creativity]. Mexico: Granica.

De Bono, E. (1994). *El pensamiento lateral. Manual de la creatividad* [Lateral thinking. Creativity manual]. Mexico: Editorial Paidos Mexicana.

De Bono, E. (1996). *El pensamiento creativo* [Creative thinking]. Mexico: Editorial Paidos Mexicana.

De la Torre, S. (1997). *Creatividad y formación: identificación, diseño y evaluación* [Creativity and formation: identification, design and evaluation]. México: Trillas.

Drucker, P. F. (2002, August). The Discipline of Innovation. *Harvard Business Review*. Retrieved on February 9, 2015, from https://hbr.org/2002/08/the-discipline-of-innovation/ar/1

Feldman, C. & Bolino, C. (2000). Career Patterns of the Self-employed: Career Motivations and Career Outcomes. *Journal of Small Business Management*, 19(38), 53-67.

Fobler, H. S. & LeBlanc, S. (1995). *Strategies for Creative Problem Solving.* U.S.A.: Prentice Hall PTR.

Gámez, G. (1998). *Todos somos creativos* [We are all creative]. Barcelona: Ediciones Urano.

Gupta, P. (2012). *The Innovation Solution. Making Innovation More Pervasive, Predictable and Profitable*. U.S.A.: Accelper Consulting.

Hellriegel, D. & Slocum, J. (2004). *Comportamiento organizacional* [Organizational behavior] (10th. Ed.). Mexico: Thomson.

Hernández, R.; Fernández, L. & Baptista, P. (2014). Metodología de la investigación [Methodology of Research] (6th. ed.). México: McGraw-Hill.

Johnson, S. (2010). *Where Good Ideas Come From*. The Natural History of Innovation. New York: Riverhead Books.

Katz, J. (1994). Modeling Entrepreneurial Career Progressions: concepts and considerations. *Entrepreneurship: Therory and Practice*, 2(19), 23-24.

Min, Hui-Tzu (2005). Training students to become succesful peer reviewers. *System*, 33, 293-308. Retrieved from http://epi.sc.edu/ar/AS_4_files/Min%202005.pdf

Olivares, E. (March 2nd, 2015). Los jóvenes llegan a la universidad sin comprender lo que leen, alerta un estudio [Young Students Arrive at College Without Understanding What They Read, Warns a Study]. *La Jornada.* Retrieved on March 3, 2015, from http://www.jornada.unam.mx/ultimas/2015/03/02/existe-una-crisis-educativa-en-

formacion-preuniversitaria-en-mexico-estudio-9948.html

Peters, R.G. (2012). *Differences Between Traditional and Progressive Education*. Wingra School. Available at http://www.wingraschool.org/who/progressive.htm

Quijano, W. (2006). *Dirección de recursos humanos y consultoría en las organizaciones* [Human Resources Management and Consulting in Organizations]. Barcelona: Icaria Editorial, S. A.

Resnick, M. (June, 2007). *All I Really Need to Know (About Creative Thinking) I Learned (By Studying How Children Learn) in Kindergarten*. Proceedings of the Sixth Creativity and Cognition Conference, Washington, D.

Rivero, V. (2002). *Soñar para diseñar* [Dream to design] (Unpublished undergraduate dissertation). Anahuac Mayab University, Merida Yucatan Mexico.

Robbins, S. & Judge, T. (2013). *Comportamiento organizacional* [Organizational behavior] (15ª ed.). México: Pearson Prentice Hall.

Robinson, K. (2006, February). Do schools kill creativity? [Film] Retrieved June 18, 2016, from http://ed.ted.com/on/KA5cHhm8

Salinas, D. (2014). *Competencias emprendedoras, motivación para emprender y productividad. Un estudio en el sureste de México* [Entrepreneurship competencies, motivation for entrepreneurship and productivity. A study in the Southeast of Mexico] (Unpublished doctoral dissertation). Anahuac Mayab University, Merida Yucatan Mexico.

Salinas, D. & Barroso, F (2016). *Eficacia de un programa de incremento de la motivación para emprender y la productividad de trabajadores a un año de haberse implementado* [Efficacy of a program for increasing motivation for entrepreneurship and employees productivity one year after it was implemented]. Proceedings of the I Anahuac Mayab International Research Congress in Administrative Science (ICAAM). June 1st- 3rd.

Senge, P. (1995). *La quinta disciplina* [The Fifth Discipline] (3rd. Ed.). Buenos Aires; Granica.

UMICH (2015). *Problem Solving. Critical and Creative thinking*. Retrieved from http://www.umich.edu/~elements/5e/probsolv/strategy/crit-n-creat.htm

Journal of Innovation Management
JIM 5, 3 (2017) 75-121
HANDLE: http://hdl.handle.net/10216/107952
SM: Sep/2015 AM: Aug/2017

Innovation Enablers for Innovation Teams – A Review

Mikael Johnsson

Blekinge Institute of Technology, Department of Mechanical Engineering, Blekinge Tekniska Högskola, 371 79 Karlskrona, Sweden
mikael.johnsson@bth.se

Abstract. This review consolidates research on innovation enablers for innovation teams, defined within this research as factors that enable a cross-functional team within an organization to conduct innovation work, to provide a deeper understanding of what factors enable innovation teams to conduct innovation work, which means that this research involves three areas to provide a holistic picture: the organizational context, the team itself, and the individuals within the innovation team. A systematic database search was conducted in which 208 relevant articles were identified and analyzed thematically way. Twenty innovation enablers related to innovation teams were identified: awareness, capabilities, climate, collaboration, culture, dedication, economy, education, empowerment, entre- / intrapreneurship, human resources, incentives, knowledge, knowledge management, management, mind-set, need, processes, strategy, and time. This review contributes to prior research a deeper understanding of what key factors enable innovative work for innovation teams. Suggestions of both academic and practical use for the identified innovation enablers are included in this review, and direction for future research is suggested.

Keywords. Innovation, Innovation Management, Innovation Enabler, NPD.

1 Introduction

Innovation is needed for companies who want to stay a long time in business (Dobni, 2006; Pattersson, 2009), where established companies most often have the economic resources required to conduct innovation work (López-Fernández et al., 2011). Most often, however, they need to reframe their organizations to support innovation (Tidd and Bessant, 2013), and innovation teams constitute one way of creating small units within the company or organization to conduct innovation work (Johnsson, 2014; Yu, 2010; West et al., 2004). They are useful for at least two reasons: first, teams are known to be effective, creative and agile, for example (Backström and Olson, 2010; Dew and Hearn, 2009; Wheelan 2013; Zuidema and Kleiner, 1994); second, multifunctional and cross-functional teams perform better than individuals (Arranz and Arroyabe, 2012). Their superior performance stems from the broad range of knowledge within a multifunctional team, which stimulates the creation of new ideas, increases the spread of knowledge and favors creative performance (Ahmed, 1998b; Backström and Olson, 2010; Kelly, 2005; Smart et al., 2007).

ISSN 2183-0606
http://www.open-jim.org

1.1 Aim, focus and expected use of knowledge from this research

This research aims to conduct a literature review to identify key factors that enable an innovation team to conduct innovation work within an organization, that is, innovation enablers for innovation teams. An innovation team is affected by the organizational context (Guzzo and Dickson, 1996; Hackman, 1990), and as the team consists of individuals, there are factors affecting both the team and its members (Backström and Olson, 2010; Wheelan, 2013). Therefore, three kinds of consideration are relevant for innovation teams: the organizational context, including management, the team itself, and the individuals within the team.

By conducting a review of innovation enablers, with a specific focus on innovation teams, this study contributes to prior research by building on already existing knowledge in the same area and providing a holistic understanding of the factors enabling innovation teams to conduct innovation, work from organizational, team and individual perspectives. Practitioners and industry can benefit from this research when creating new innovation teams or when guiding and coaching already existing ones.

1.2 Definitions of terms used within this review

An innovation enabler is defined within this review to be comprised of factors facilitating an innovation team in conducting innovation work within an organization. This definition builds on the definitions of "innovation," "innovation work" and "innovation teams."

An innovation is said to be an "implementation of a new or significantly improved product (or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" (OECD, 2005. p. 46). West et al. (2004) claim an innovation to be defined by the application of ideas in practice, by which someone must benefit. Andersson (1996), Lans (1997) and VINNOVA (the Swedish governmental agency for innovation systems) offer a similar definition, but add that value has to be created. I build on these prior definitions and define innovation within this review as something new that is developed and successfully implemented on the market (entailing value creation), whether an external or internal market. To make an innovation happen this requires all efforts necessary to implement the developed idea in the market (Andersson, 1996; Baxter, 2002; Johnsson, 2009; Michanek and Breiler, 2004; Ottosson, 2012; Tidd and Bessant, 2013), efforts that are in this context defined as innovation work.

An innovation team is within this review defined by a combination of the definitions of innovation and team. A group and a team are not the same. A group is defined as a complex social system of two or more people embedded in an organization (Hoegl, 2005) striving towards common goals and a structure to fulfill the goal (Wheelan, 2013). The members in a group may not yet have "found each other" (Backström and Olson, 2010) or developed efficient ways of working together (Wheelan, 2013), and they may not perceive themselves or other members as being part of a team, according to Hoegl (2005). A team is a social system of people embedded in an organization, whose members perceive themselves as such and are perceived as members by others (Hoegl, 2005; Wheelan 2013). To become a team, a group has to

emerge through a number of stages throughout which one of the main tasks is to have a common goal to reach (Tuckmann and Jensen, 1977; Wheelan, 2013), but as the emergence process and related team status are not focused upon in this review, the term "team" is used regardless of it current status. Therefore, the definition of an innovation team is a team with the purpose of conducting innovation work within an organization. However, within the research conducted, the term "group" was included in the literature review to ensure no relevant articles were excluded.

1.3 Why enablers and not barriers?

Is an innovation enabler the opposite of an innovation barrier? Research shows that, for example, some barriers to innovation constitute financial constraints and limited budget, resistance to change, no time for innovation work (Hassainen and Dale, 2012; Orcutt and AlKadri, 2009;) or bureaucracy (Adams et al., 2006; Amabile 1998; Backström and Olson, 2010; López-Fernández et al., 2011). On the other hand, in the way that innovation is defined one can understand it as a complex situation to handle, and one could expect problems (barriers) to appear along the way. Problems can in some cases even be seen as a positive to innovation work, as they require creative solutions that might lead to completely new solutions (Johnsson, 2009). Two methods to apply to innovation work are suggested by Ottosson (2012): the first is to deliberately aim to solve 80% of a work task and leave the remaining 20% to be solved later on. This method means that problems of different kinds can be left to be solved at better times or when new knowledge concerning the work task is generated; the second methodology is to compare innovation work to running water. As running water passes rocks or other obstacles "without problem," one can use the same metaphor when conducting innovation work. Chose another path if obstacles bar the current path. The bottom line is this: Do not let problems, barriers, hindrances, roadblocks, or holdups of any other description stop the team from reaching the goal. Instead, "just take another path." My conclusion is that barriers to innovation are just a part of the innovation team's process to handle, finding solutions whenever they appear. For that reason, this review focuses only on innovation enablers.

1.4 Previous knowledge on innovation enablers

A literature review with focus to reveal reviews on innovation enablers was conducted to gain knowledge on the research field. Twelve reviews were detected, demonstrating a scattered area of 41 explicit factors considered to enable innovation work. From an organizational perspective seven enablers were identified, i.e. *collaboration* (Aagard & Gertsen, 2011; López-Fernández and Serrano-Bedina, 2011; Ross et al., 2012; West et al., 2004; Yu, 2010, *culture* (Aagard & Gertsen, 2011; Balsamo et. al., 2008; Denti and Hemlin, 2012; Smith et al., 2008; Yu, 2010, *education* (Aagard & Gertsen, 2011; West et al., 2004; Yu, 2010), *knowledge* (Aagard & Gertsen, 2011; López-Fernández and Serrano-Bedina, 2011; Ross et al., 2012), *management* (Aagard & Gertsen, 2011; Denti and Hemlin, 2012; Gambatese and Hallowell (2011); López-Fernández and Serrano-Bedina, 2011; Smith et al., 2008), *strategy* Aagard & Gertsen, 2011, Manley, 2006; Smith et al., 2008) and *structure* (Denti and Hemlin, 2012; Gambatese and Hallowell (2011); López-Fernández and Serrano-Bedina, 2011; Smith et al., 2008; Yu, 2010).

From of a team-perspective there were four enablers identified, i.e. *climate* (Balsamo et. al., 2008; Denti and Hemlin, 2012; Kianto, 2011), *collaboration* Gambatese and Hallowell, 2011; Kianto, 2011), *diversity* Kianto, 2011; West et al., 2004), *management* (Denning, 2011; West et al., 2004)
From the individual perspective there were all unique innovation enablers, where the areas concern how the individual perceive demands (West et al.2004), is taking personal initiative (Denti and Hemlin, 2012), is self-disciplined (West et al., 2004) or is self-efficient (Denti and Hemlin, 2012).
The identified reviews were all conducted in a time span of a few years (2008-2012), except for one paper that was conducted a few years earlier (2004), providing short descriptions to each enabler. This motivates another, more in deep literature study, to reveal explicit and hidden factors enabling innovation team's innovation work where the focus is on the innovation teams' point of view alone.

1.5 Research Question

The main research question explored within this literature review is the following:

What factors are considered to enable an innovation team to conduct innovation work, and how can they be categorized?

2 Methodology

2.1 Research design

The research design of this review is based on a three-stage procedure: The first stage is the planning, which is to say the development of a plan for conducting the review, along with determining the aim of review, the protocol and criteria for the search for, selection of and analysis of the results. The second encompasses the execution, comprising activities such as developing keywords, conducting a review and analyzing the results. The third stage is the reporting, which involves suggestion of the academic and practical use of the results of the review (Tranfield et al., 2003).

2.2 Planning the review

This review was planned by defining its aim and the terms "innovation," "innovation team," and "innovation enabler," along with the choice of "enabler or barrier" to review. This definitional work was followed by developing a protocol describing how to relate to the results from the databases. The aim of the review was to identify both explicit and implicit innovation enablers for innovation teams. The selection of articles from databases was not based only on identifying specified keywords alone, but also on interpretations of titles and abstracts, in accordance with Schon's (1991) and Boyatzis's (1998) methods, to identify innovation enablers.

2.3 Executing the review

The keywords were developed from the starting point of "innovation enablers." Synonyms for "enablers" were identified using Microsoft Word's (version 2011, 14.4.6) tool for suggesting synonyms, followed by the identification of new

synonyms derived from these first synonyms, using the same tool. This process was iterative, whereby one synonym led to another. No consideration was made of whether the synonyms were likely to be used or not in the research. When the synonym tool could not suggest any more synonyms, the keywords were rephrased to cover a broader area (e.g. "innovation enablers" and "enablers for innovation"). In total 47 keywords to cover "innovation enablers" were identified. The search-engine Summon was used to test and clarify what keywords were to be used in the following full-scale search, which resulted in an adjusted list of 24 keywords.

Table 1. The table demonstrates the synonyms for "innovation enablers" that were used as keywords in the database search.

#	Keyword [innovation enabler]
1	"innovation enablers"
2	"innovation facilitators"
3	"innovation drivers"
4	"innovation promoters"
5	"innovation supporter"
6	"innovation pros"
7	"innovation incentives"
8	"innovation encourager"
9	"encouraging innovation"
10	"innovation inspiration"
11	"innovation creators"
12	"innovation boosts"
13	"innovation spurs"
14	"innovation inducements"
15	"innovation impetuses"
16	"innovation impulses"
17	"innovation motivators"
18	"innovation stimulus"
19	"stimulating innovation"
20	"motivating innovation"
21	"boosting innovation"
22	"creating innovation"
23	"supporting innovation"
24	"enabling innovation"

As the context of innovation teams include the perspective of the organization, the team and the members of the team, a list of 27 keywords based on synonyms for

"organization," "management," "innovation team" and "individuals" was developed by using the same tool as that used to generate synonyms for "innovation enablers."

Table 2. The table demonstrates synonyms for "organization," "innovation team" and "individuals."

#	Keyword [perspective of innovation enabler]
1	"review"
2	"team"
3	"innovation team"
4	"group"
5	"innovation group"
6	"individual"
7	"grassroot"
8	"operator"
9	"operator level"
10	"worker"
11	"worker level"
12	"employee"
13	"employee level"
14	"blue-collar"
15	"blue-collar level"
16	"white-collar"
17	"innovation work"
18	"work"
19	"innovation job"
20	"job"
21	"organization"
22	"management"
23	"management level"
24	"top management"
25	"upper management"
26	"senior management"
27	"middle management"

As the keywords were developed in an iterative process, an adjusted list of 10 keywords regarding the perspective emerged from the number of hits when conducting the research in the database.

Table 3. The table demonstrates keywords that emerged from Table 2 and were used in the database search.

#	Keyword [perspective of innovation enabler]
1	"review"
2	"team"
3	"innovation team"
4	"group"
5	"innovation group"
6	"individual"
7	"innovation work"
8	"work"
9	"organization"
10	"management"

2.4 Database search

The data base search engine Summon was used between January to March of 2014. It was limited to a search for full-text online sources that were scholarly articles or academic journal articles, written in English. The research areas of business, economics, education, engineering, science and social sciences were included in this review. The reason these research areas were used is that innovation is a multidisciplinary area of study (as clarified in the definition of innovation). Another reason is that academic and industry interest in the work of innovation teams is connected to outcomes, such as performance and learning, that are connected to certain research areas.

All keywords in Table 1, Table 2 and Table 3 were used individually and in combination in four ways, as demonstrated in Table 4.

Table 4. The table demonstrates of how the keywords were used in the search engine Summon when identifying relevant articles from innovation enablers.

Search	Search in Title	Search in Abstract
	Keyword used in:	Keyword used in:
#1	Table 1	-
#2	Table 1 AND Table 2	-
#3	Table 2	Table 2
#4	Table 3	Table 1

When a combination of keywords did not generate any hit, the spelling was controlled

and adjusted if needed. The keywords were used crosswise in Summon, as demonstrated in Table 4, generating 2,402 title hits.

2.5 Analysis of results

A two-step-process was used to reduce the identified titles to 211 relevant articles. The first step was to identify relevant articles in which a title-selection methodology was used, where three selection criteria applied: First, the explicit terms such as "innovation team" or "innovation group," or words that could be interpreted as such, had to be a part of the title, or the article had already to have conducted a review regarding innovation enablers. Second, the abstract also had to explicitly discuss innovation enablers or indicate that innovation enablers were explicitly discussed in the article. Third, it was necessary that the article offer an organization-, team- (or group-), or individual-centered perspective. This first step reduced the number of relevant articles to 377 articles.

In the second step, the abstracts were read based on the criteria that there should be indications that the author(s) had put content to the innovation enabler; in other words, the innovation had to be described in a way that it could be understood and become useful to an innovation team's innovation work (e.g. a summary bullet-point list would not be sufficient to add value to this review). This step left 211 articles, which were read and thematically analyzed (Boyatzis, 1998; Schon, 1991) to identify innovation enablers. The focus was to identify single keywords within the identified articles that could be interpreted to represent an innovation enabler that may affect an innovation team directly. In some cases the authors demonstrated one key or main innovation enabler in an explicit way, while in other cases one main innovation enabler consisted of sub-enablers. In total, 46 articles contributed with data to several innovation enablers. The identified keywords were used to cluster them into themes, and organized based on relevance to the organization, team or individual. In total, 20 innovation enablers were identified, and they are presented in the following chapter, where each and one of them contains a description of its importance to innovation and how it might be applied in operational work of relevance to an innovation team. However, a few of the enablers affect the team on both the organizational and team level and are therefore demonstrated across several categories.

3 Results

Based on the thematic analysis, 20 innovation enablers were identified and divided according to their relevance at the organizational, team or individual level, demonstrated in alphabetical order in this section. The identified enablers sometimes overlap, and several of them are embedded as enablers in more than one perspective, as demonstrated in Table 5.

3.1 Organizational perspective

Climate. A climate refers to the manner of working together that the team has evolved based on shared perceptions of policies, practices and procedures (Anderson and West, 1998). Climate is less stable than culture and can be seen as an expression

of culture at a specific time. Companies that create a positive climate for innovation do much better at product innovation (Cooper, 2013; Kianto 2011; Nybakk et al., 2011). An organization's creativity comes from employees, whereas the climate becomes important in the sense that it can motivate employees to be creative. An innovative climate is one key component of an innovative company, and all companies, no matter the size, can benefit economically from such a climate (Nybakk et al., 2011).

Prior research agrees that there are several aspects included in an innovative climate. However, there are some differences in how they are expressed and how many aspects scholars consider important when defining an innovative climate. Ekvall (1996) suggests ten factors that demonstrate a creative climate within an organization: challenge or motivation, freedom, idea support, liveliness or dynamism, playfulness or humor, debates, trust or openness, conflicts, risk taking, and idea time. On the other hand, Watkins and Marsick (1996) demonstrate seven factors that contribute to innovation: continuous learning, dialogue and inquiry, team learning, embedded systems, empowerment, system connections, and leadership. Ismail (2005) conducted a study in which these factors were compared, and the result was that Watkins and Marsick's factors made more significant contributions in explaining innovation than Ekvall's factors did. A few years later, Crespell and Hansen (2008) developed and validated six factors associated with innovation climate: supervisor encouragement, team cohesion, challenge, autonomy, openness to innovation, and availability of resources. Balsamo et al. (2008) evaluate an organizational climate for innovation using the VIPAT tool, and they specify nine variables: challenges and involvement; freedom; trust and openness; idea time; playfulness or humor; absence of conflicts; idea support; debates; and risk taking.

Factors similar or identical to those above are have been suggested by other researchers: for example, autonomy (Bright and Godwin, 2010; Cooper 2005; Crespell and Hansen, 2008); empowerment (Harborne, 2003; Denti and Hemlin, 2012); space for innovation (Harborne, 2003; Leavy, 2005; Weiss et al., 2011); self-confidence in sharing ideas with others (Johnstone et al., 2011); leadership supporting internal and external networking (e.g. cross-boundary, team-work or customer relationships) (Balsamo et al., 2008; Cooper, 2005; Johnstone et al., 2011, West et al., 2004); recognition for those who innovate (Gamatese and Hallowell 2011); trust in other team members (Nanda and Singh, 2009); the involvement of people in innovation projects (Cooper 2005; Harborne, 2003); acceptance of different settings for innovation projects (Harborne, 2003); and the creation of a learning and development climate in the organization (West et al., 2004). Further on, Cooper (2005) suggests leadership to be with respect to boundary management, resource setting, and support, and all favored a model for good leadership around "management as service rather than seniority," "hands-off management" on a day-to-day basis, being relaxed, taking time to listen and being supportive in discussions with other people.

Culture. Culture is defined as a set of shared values, norms, and knowledge within a firm (Crespell and Hansen, 2008; Hauser, 1998; Nanda and Singh, 2009), which are partly conscious and partly subconscious, but are very hard to change (Hauser, 1998). The culture influences the behavior of members within the company, as culture

represents the deepest level of basic values, assumptions and beliefs shared by the members, and it is established by actions, especially from leaders and managers (Chen et al., 2012; Sarros et al., 2008), such as hiring individuals with a range of abilities and interests or a variety of backgrounds and personalities, and heavily involving peers in the selection process (Leavy, 2005; Stempfle 2011). A strong culture ensures that everyone in the organization is on the same track (Nanda and Singh, 2009) and plays an important role in a firm's innovativeness (Hauser, 1998), where the culture has different roles in the innovation work. For example, in the search for and choice of problems to solve, and in the generation of solutions and implementation of solutions, Hauser (1998) and Hardakker (1998) found that an innovative culture contributed to making NPD faster to market. Further, Lemon and Sahota (2004) have identified four archetypes of culture: controlled, fuzzy, inspirational and cultivated, where a successful company needs to be able to shift from a controlled environment to a cultivated environment to become truly innovative.

Economy. Economy as an innovation enabler has been discussed in prior research in different ways, where economy becomes almost equal to what an organization invests in an innovation project in terms of resources such as time and knowledge, along with financial resources and human resources (Panayides, 2006; Smith et al., 2008). These resources are important not only for functional support, but also to show that the innovation project is valuable to the organization (Nanda and Singh, 2009).

The difference between small and large companies is huge in many respects. Small companies can be more agile and entrepreneurial in their innovation work, but large companies most often have more financial resources to spend on innovation work (López-Fernández et al., 2011) like creating a customer or supplier involvement. However, there is a need of leadership who wants to invest in risky innovation projects (Cooper, 2013). Furthermore, the research suggests that in increasing the company's capability for innovation, managers should support not only the technological or non-technological side of innovation (Camisón and Villar-López, 2012), but also the development of client relationships. This support arises through top management showing commitment, encouraging the development and implementation of new ideas and processes, and rewarding creativity that can occur anywhere in the organization (Panayides, 2006).

Management. Organizations need to continuously innovate to remain competitive (Brennan and Dooley, 2005; Dobni, 2006; Dooley et al., 2000). Management innovation is necessary to fulfill this need, and its drivers are strength of competition, threat of market entry and speed of technological change (Hecker and Ganter, 2013). Techniques to speed up management innovation include consciously selling the importance of management innovation to the organization, questioning, creating a problem-solving culture, and exposing employees to many different types of environments and different countries of operation, if available. They also include building a capacity for low-risk experimentation to increase the chance of implementation without crippling the functioning of the whole organization, using external change agents to explore new ideas, and being and acting like a serial management innovator (Birkinshaw and Mol, 2006). There is also a need to overcome managers' mental models when they reject disruptive innovation. These managers'

strategies are built on rewarding incrementalism, ignoring the positive aspects of disruptive innovations, focusing on historical perceptions of success, creating perceptions of success that involve great efforts, and beliefs in the face of disconfirming information (Lettice and Thomond, 2008). However, there is also a to adjust the organization's management in accordance with its stage in the organization's life cycle (Koberg et al., 1996). The age of management also matters, since younger managers are most often trained in new technology and have the time to wait for pay off. This fact makes young managers more willing to invest in innovations based on new technology. Older top managers are less willing to invest in innovation, as they are at the end of their career and worry more about the short-term response to a project; they also do not invest in long-term projects (i.e. innovation projects) (Ahuja et al., 2008).

Innovations, as such, need a medium- or long-term perspective to be implemented, which requires a strong commitment related to managerial stability (Longo, 2007), along with access to skilled employees and managerial staff (Clark, 2012; Parolin et al., 2013) and managers who develop conditions to start cooperation between functions and organizations to make them more competitive (Parolin et al., 2013). The ongoing commitment of top and middle management is the main key according to Longo (2007), and Taylor and Helfat (2009) argue that middle management is the link to economic, structural, social, and cognitive activities, which are the corner stones of strategic innovation. Top and middle management play different roles. While top management is expected to establish and communicate its vision and broad goals and to commit middle management, who should plan and implement the entire innovation process, to these principles. This implementation requires a broad portfolio of skills and competences (e.g. health care planning, organization, behavior awareness, as well as negotiation and persuasion capabilities), which requires the presence of a middle management team in charge of the entire issue, a team that is sufficiently solid and integrated. To change an organization takes a long time (6–10 years), and the worst hurdles are in the second phase, after the early enthusiasm has waned, and this is why commitment is the key (Longo, 2007).

A formally structured young firm is less innovative than an informal one; however, formalization in older organizations does not have negative impact on innovation (Martinsuo et al., 2006). A flat, networked structure that facilitates communication and encourages cross-functional group operations represents the most advantageous style. Still, it is important that the management demonstrate leadership and encourage personnel to operate effectively, as teams (Dooley et al., 2000) that support divergence and convergence (Adamides and Karacapilidis, 2006) but also have the opportunity to work individually in the early phases, spurring innovation (Černe et al., 2013). Structures also include the implementation of efficient innovation processes that feed the organization with ideas to be implemented to remain competitive (Brennan and Dooley, 2005). In such processes, internal and external networks, together with customers, competitors and consultants, provide important sources of new ideas which can influence the introduction of these practices (Mol and Birkinshaw, 2009; O'Brian and Smith, 1995).

Strategic management is defined as a process that links strategic planning, implementation, and measurement in a continuous cycle of learning, building

competencies, and achieving desired change (Olsen and Haslett, 2002). To create value by optimizing innovation processes in networks has become a highly interesting topic on a managerial level, as this practice creates new products over the short term and long term, and it generates intangible values (e.g. technology leadership and a secured position on the market) (Eschenbaecher and Graser, 2011).

Transformational leadership has important effects on creativity at both individual and organizational levels, and transformational leadership influences employees' creativity through psychological empowerment (Gumusluoglu and Ilsev, 2009). Management should broaden its understanding of individuals' need for autonomy and structure for motivation and commitment (Mansfeld et al., 2010), and it should ensure co-workers that they will not be punished for failure (De Jong and Vermeulen, 2003).

Furthermore, leaders of complex organizations should help the organization develop appropriate structure, innovation, and fitness. They should also support flexible thinking, act like symbols and enable useful behaviors (Marion and Uhl-bien, 2002). When aiming for radical innovation, the management must support capabilities and skills in three different phases: discovery (i.e. to create, recognize, elaborate, and articulately identified opportunities); incubation (i.e. to develop business plans out of the identifies opportunities); and acceleration (i.e. to ramp up the untried business to a point where it can stand on its own) (O´Connor and DeMartino, 1997)

High degrees of management support in projects has positive effects on speed to market, team learning from team crises and team anxiety. Processes regarding product development and commercialization are faster, and idea generation is more efficiently executed. However, a low degree of management support in projects does not affect the project in the opposite way, but team anxiety has been found to influence the capabilities in the product-development stage regardless of low or high level of management support. This influence means that management could encourage team members to turn stressors into high performance. A low level of encouragement is beneficial for team learning, and a high level of encouragement speeds up the product-development process. Management could support and help team members to overcome problems they face by giving direct help when needed. When teams are in crisis or anxiety, they need high levels of emotional support and encouragement from management to solve problems and speed up the development process and to launch the product successfully (Akgün et al., 2007).

To lead in the direction of innovative behavior, a leader must act as a role model, stimulating the intellectual diffusion of knowledge, spreading and sharing information and knowledge. The vision should be clear and should communicate in what direction to seek for ideas, but at the same time the leader should consult, rather than order results, which is achieved by delegating tasks where co-workers can explore and develop new insights. Even though the work should involve freedom, support of and feedback on work are essential, as well as recognition of achieved results and monitoring of progress and deviations. However, innovation work is not a single person's work; it takes various kinds of resources (De Jong and Den Hartog, 2007; Gilley et al., 2008).

An effective leader of an innovative workforce needs to foster both exploration and exploitation and has to be capable of flexibly switching between the three elements of ambidextrous leadership: fostering exploration by applying open leader behaviors,

which include encouragement to do things differently, exploration and experimentation; giving room for independent thinking and acting; and supporting attempts to challenge established approaches (Rosing et al., 2011). Furthermore, management must consider to what extent the organization is mature enough to conduct exploration work. If there is too much tension within the organization, the development phase should be performed in external test facilities, but this tactic requires experienced project managers that can handle ambidextrous management (Hollen et al., 2013). Management needs, in addition to the ambidextrous leadership, to manage the creation and facilitation of knowledge creation in innovation projects. When top management increases its formal control, it stresses explicit knowledge, which may risk missing the vital interplay between tacit and explicit knowledge needed for knowledge creation, which in turn may reduce the overall capacity for knowledge creation and, ultimately, innovation (Richtnér and Åhlström, 2010).

However, the mix of exploring and exploiting (ambidexterity) innovation is of essence, whereas a first-mover strategy can hinder strategic innovations and a follower strategy could enhance strategic innovations if the knowledge is transformed into new developed knowledge that could be used for commercial purposes (Gebauer et al., 2012). The conflict lies in aiming for being first and being best. Innovativeness usually relates with being first, but this form of innovation is properly referred to as exploratory innovation, while another kind, exploitative innovation, is closely linked to improvements aiming at being best (Kollmann and Stöckmann, 2010). However, when planning for ambidextrous innovation work, one should consider that resource orientation (i.e. distinct resources and capabilities) improves innovation performance, while market orientation tends to result in incremental improvements (Ford and Paladino, 2013). Nevertheless, if a company concentrates only on its organizational capabilities, it will not succeed in terms of stability and sustainability (Kask, 2011). In addition, strategic ambidexterity suggests that an entrepreneurial orientation is of extra importance. The reason is that risk taking, innovativeness, pro-activeness, competitive aggressiveness, and autonomy stimulate exploratory innovation, whereas only pro-activeness and competitive aggressiveness facilitate exploitative innovation (Kollmann and Stöckmann, 2010). Another dimension to strategically plan for ambidexterity is the timing of additional innovative activities. The longer it takes for a company to launch new innovative activities, the lower its innovation performance will be, which of course is beneficial for “fast companies” over “slow companies” (Kuckertz et al., 2010). For an overall perspective, organizations need strategies that embrace portfolio management and include budgets for big and risky projects; scoring models, as opposed to financial models, incorporate step-wise investment, seeking data confirmation unconnected to ordinary gates and launching risky projects through alternative processes (Cooper, 2013).

Strategy. Previous studies have shown that firms with an innovation strategy perform better when the innovation strategy consists of four dimensions: first, leadership priority for product innovation; second, leadership priority for process innovation; third, leadership priority for business-systems innovation; and fourth, resource commitment to research and development to gain competitive advantage (Nybakk et al., 2011). These four dimensions are useful for providing new offerings or experiences that excite the customer, to stay ahead of and outperform competitors, when entering new market segments, when creating new businesses or when building a product portfolio (Bowonder et al., 2010). Strategic innovation capacity is strengthened when managers deliberately install specific learning mechanisms on absorptive capacity, whereas knowledge recognition, assimilation and exploitation are key areas (Berghman et al., 2013).

On the operational and managerial level, a suggested strategy to apply is cooperation rather than competition. However the focus of the innovation work should be on the final market (Gibbert et al., 2002; Hine and Ryan, 1999). A company could develop innovative solutions at the level of a local or global market, but the circumstances are not the same and must be treated in that way. This difference means that both primary and secondary environmental factors should be considered in strategic decision-making and in improvements to dynamic capabilities (Kask, 2011).

As firms move towards establishing closer relationships with their suppliers, partners, and even competitors, a new paradigm of strategy, value creation, and organizational design appears to be emerging. Competitive advantage is based on learning and absorbing new sources of knowledge, no matter where they may be created, and is a key driver that sustains competitive advantage (Lei, 2003). However, if an organization wants to achieve innovative goals, these must be communicated and understood by all employees, enabling those employees to contribute to the expected goal in their day-to-day work (Smith et al., 2008).

Time. Management must show commitment by investing time and money to encourage the development and implementation of new ideas and processes (Yesil et al., 2013) and at the same time not overload individuals with projects (Nanda and Singh, 2009). As an employee, one should know how much time and effort one can spend on a pet project, where some organizations allocate time (e.g. 15% of the time) to be spent on generating new ideas and working on employees' favorite projects (Nanda and Singh, 2009.)

3.2 Team perspective

Climate. All the factors presented regarding the climate, from the organizational perspective above, are valid from the team perspective as well, as the team can be seen as a small organization in itself (Backström et al., 2011). More specific to teams, though, team potency has been found to be important to fostering an innovative climate (i.e. attitudes such as "this team believes it can become unusually good at producing high quality work" and "this team feels it can solve any problem it encounters") (Gil et al., 2005). By contrast, it is assumed that leaders generally have a significant influence on the creation of a climate in which they, for example, act as role models, support ideas and participate in work (Denti and Hemlin, 2012).

Collaboration. Competition is replaced by cooperation when aiming to add industry value (Hine and Ryan, 1999). Both short- and long-term collaboration or cooperation can result in innovation as a result of being more open to new ways of thinking and doing (Smith et al. 2008), whereas innovation teams are affected in two ways, namely by internal and external collaboration. Importantly, though, it may take a long time to build a good relationship, but it takes very little time to destroy one (Bush and Frohman, 1991), as collaboration builds on social interaction between individuals (Adamides and Karacapilidis, 2006). Free and open communication and information flow must be in place across both the short and long term (Balsamo et al. 2008; Bossink, 2004; Bingham, 2003; Bush and Frohman, 1991; Johannessen and Olsen, 2011; Nanda and Singh, 2009; Romero and Molina, 2011). The communication serves as a tool for knowledge sharing (Yesil et al., 2013) and should be clear, including directions, status and goals (Aagaard and Gertsen, 2011), whereas vision, strategy and operations are also of importance (Denti and Hemlin, 2012; Mansikkamäki et al., 2007; Nanda and Singh, 2009).

Cross-functional work, as internal collaboration, saves not only time and money, but also increases production and process improvements, where intangible results such as improved team-work, communication and involvement within and across groups can be seen immediately (Balsamo et al., 2008). Cross-functional teams, however, depend on factors such as open and collaborative organizational culture, participatory management style, input from sales (Cooper, 2005), and employees open to discussing and implementing new ideas within their teams (Morgan et al., 2004; Smith et al., 2008). The characteristics of their work are an overlap of design and construction phases (Bossink, 2004; Gamatese and Hallowell, 2011), making team boundaries more permeable (Aagaard and Gertsen, 2011; West et al., 2004). These characteristics also constitute interaction between the involved parties, various departments, and the employees involved in the innovation process (Nanda and Singh, 2009; Panesar and Markeset, 2008; Salge et al., 2012). On the individual level, cooperation depends on four basic attributes of the potential team members: first, clearly defined and specific specializations for every one of the members; second, the team members' clear and visible beliefs and practice of interdependence, together with some uniting attributes (e.g. their shared project); third, the members' capacity to tolerate differences and to find them enriching, a critical source of interdependence; and fourth, the team members' capacity to use various methods supporting their cooperation (Matjaz̆ et al., 2006).

External collaboration that affects innovation teams was clustered into six groups: first, users, i.e. to interact with end, lead or extreme users to gather knowledge of the users' true environment (Ross et al. 2012; Yu, 2010); second, customers, i.e. to discover customer needs and to understand customer behavior, markets, and opportunities [Bush and Frohman, 1991; Cooper, 2005; Coviello and Joseph, 2012; Kodama, 2000; Morgan et al., 2004; Panesar and Markeset, 2008; Yu, 2010] and to involve the customer in the development process [Bossink, 2004; Coviello and Joseph, 2012]). The benefits of incorporating customers' ideas offer a faster and more efficient way to innovate than using the traditional R&D approaches (Romero and Molina, 2011), and customers, as a source of innovation, are significantly linked to higher levels of innovation-related sales (Laursen, 2011), but co-creators should be rewarded to send signals that their input is appreciated (Romero and Molina 2011).

Cheng et al. (2012) come the conclusion that customer involvement is not as important in new service development as in new product development, perhaps because companies lack of knowledge in building prototypes. Third, suppliers keep knowledge of new technology updated (Yu, 2010), develop new innovative applications (Bossink, 2004), or improve the effectiveness and efficiency of operations, maintenance and processes (Panesar and Markeset, 2008). Collaboration with suppliers is more important to larger companies than to small and medium-sized companies, as these are not as entrepreneurial as large companies (Jenssen and Nybakk, 2009), but the collaboration requires flexibility and sharing of ideas from both parties to support innovation (Mooi and Frambach, 2012). Fourth, networking allows for collaboration and sharing of knowledge with experts (Hurmelinna-Luakkanen, 2011; Mele et al., 2012). In practice, this contribution means collaboration with experts and joint business networks (Ross et al. 2012), along with participation in conferences and courses (Jenssen and Nybakk, 2009). The benefits of networks are increased information flow (Hemlin and Olsson, 2011; López-Fernández et al., 2011), productive innovative climate (Cooper, 2005) and accumulated management know-how and intangible assets, such as brand image and prestige (López-Fernández et al., 2011). Fifth, partners facilitate strategic alliances and long-term relationships that are used for sustainable innovation results (Bossink, 2004); partnership with universities, in particular, increases a company's competitive advantage (Aagaard and Gertsen, 2011; Morgan et al., 2004). Furthermore, Birkinshaw et al. (2007) suggest that it could be of value to seek new networks in distant areas and to identify potential strategic and unusual partners when aiming for discontinued innovations, but the key questions to ask regarding the plausible innovative performance is how much a company has to learn and how well it is able to learn from its partner(s) (Sampson, 2007). Diversity in technological capabilities between partners is required for innovation, but not too big a divergence, as partners may in that case have problems learning from each other (Sampson, 2007). When creating a R&D network, Mansikkamäki et al. (2007) suggest that the involved parties have "the right attitude," respectful confrontation with other parties, excellent communication skills, and a strong will to work together; and it should be the case that top management's interaction with external R&D is positively related to product innovation (Jenssen and Nybakk, 2009). As a complement to alliances, Noke et al. (2008) suggest dalliances with companies having slow innovation processes, with no strings attached and no commitments other than ordinary business agreements, where they can benefit from learning and increasing disruptive innovation capacities. Sixth, competitors strengthen creativity, learning and knowledge stock, and innovation capabilities (Bucic, 2012; Morgan et al., 2004). Collaboration with competitors is recommended by Ritala and Hurmelinna-laukkanen (2009) as well, but they believe that IPR issues should be considered before entering into any collaboration of this kind. On the other side, research shows that companies tend to overestimate the risk of losing intellectual property while underestimating the benefits of exchanging ideas with external partners (Stempfle, 2011). However, when starting up new joint innovation projects, one strategy may be to avoid putting too much emphasis on details in contracts, which kills innovation, rather securing the collaboration as some kind of agreement providing trust in such innovation work (Paasi et al., 2010).

Culture. Tolerance for failure is one key feature of an innovative culture, according to Aagaard and Gertsen (2011), but Johannessen and Olsen (2011) highlight the importance of communication capabilities as one of the major factors when building a culture of innovation, where the benefit is that the temporary mind-set in innovation projects becomes stationary and well familiar. Other researchers highlight multiple factors as a complex system that together contributes to an innovative culture. Factors such as leadership, strategy, risk-taking, empowerment, autonomy, internal and external communication and collaboration, organizational structure or learning, and trust are identified as enablers of an innovative culture, and these can be seen as enablers of an innovative climate (Balsamo et al., 2008; Claver et al., 1998; Denti and Hemlin, 2012; Donate and Guadamillas, 2011; Hauser, 1998; Leavy, 2005; McGurk and Baron, 2012; Morgan et al., 2004; Smith et al., 2008; Steele and Murray; 2004).

Economy. As mentioned above, the need for economic consideration is demonstrated in multiple dimensions. A dedicated budget and time can more quickly lead to technical innovation if combined with autonomy, but there is also a need for technical problem-solving ability achieved through cognitive resources and problem-solving capacities (West et al., 2004). Financial resources are also needed up to a certain point, or creativity will be limited as a result of people being too preoccupied with seeking financial resources, but financial resources above this point can have a negative impact on creativity (Nanda and Singh, 2009). Ross et al. (2012) suggest that a one could make a small investment to create a proof of concept that might lead to larger investments from investors.

Education. Highly innovative organizations create and maintain a learning environment by keeping the knowledge and skills of the employees up to date (Tan, 2013). Organizations with high learning orientation tend to benefit from, for example, knowledge and mistakes, generating new ideas and developing innovations (Smith et al. 2008). Training or education is directly related to identifying opportunities of innovation and has become a tool for the improvement of companies' human resources (Bozeman, 2000), for how innovation processes are handled and for planning for uncertainty (Cobo, 2013). Education in innovation skills has been developed for decades, including a focus on practical skills such as problem identification, including sketching, problem solving, decision making, and production; communication skills; and team skills (Petty, 1983; Tushman and Nadler, 1986). One important lesson, according to Petty (1983), is that the best results do not arise from engineering courses, since most often a tight timetable decreases creativity, but design projects with strong industrial interactions have positive effects on creativity. The technological development with the Internet and web-based technology has offered a movement from face-to-face sessions towards online learning and blended learning, which has in turn led to rapid education but also new pedagogical skills to tackle complexity and information overload from the Internet (Anghern and Nabeth, 1997; Chou and Chou, 2011). Along with such technological development, current research points out an increased focus on soft skills, that is, non-technical skills such as creativity and problem solving (Nanda and Singh, 2009), collaboration critical thinking, contextual learning, searching, synthesizing information, self-direction and creativity (Cobo, 2013). The current research also highlights the need to practice opportunity identification (e.g. to find ideal systems on imaginary basis, use unexpected resources, identify contractions within a system, trim

some elements in an existing product, add another purpose to a product, etc.) (Tan, 2013). An effective learning model is to strive for shared mental models by working with reflection and experimentation (Gieskes and Van der Heijden, 2004) and to supply educational environments including course development, collaborative learning and evaluation (Chou and Chou, 2011). However, lack of time to learn (Timmermans et al., 2011), bad preparation (e.g. as a consequence of a poorly structured agenda, poor time keeping or employees' lack of interest in learning) can significantly reduce the efficiency and effectiveness of sessions (Nanda and Singh, 2009; Evans and Waite, 2010).

Empowerment. The literature supports the view that employees who are empowered and autonomous have a greater degree of control over their work. This degree of control means that employees feel comfortable in their role as innovators in their own work environment (Bright and Godwin, 2010; Brown, 2005; Cooper 2005; Crespell and Hansen 2008; Smith et al., 2008). Empowering them to be innovate is one of the most effective ways to mobilize the energies of people to be creative (Harborne 2003; Denti and Hemlin, 2012; Nanda and Singh, 2009) and have the ability to adopt opportunities faster than others (Manley, 2006). Combined with leadership support and commitment, empowerment gives people freedom to take responsibility for innovation (Nanda and Singh, 2009; Smith et al., 2008), where transformational leadership was positively related to innovative behavior and transactional leadership was negatively related to innovative behavior (Denti and Hemlin, 2012). Freedom as a core value in stimulating creativity is manifested in autonomy, empowerment and decision-making. A balance between operational and strategic autonomy leads to innovation. Employees should be given autonomy concerning the process, but not necessarily the ends. Autonomy around the process fosters creativity because it strengthens the employees' sense of ownership over a project or a situation (Nanda and Singh, 2009). However, too much autonomy leads to a lack of focus, and too little operational autonomy creates a sense of rigidness. Efforts should be made to minimize the number of major projects each person is assigned to, or they will likely get lost, as one cannot expect people to do anything but step from the top of each pile to the next. It is shown that not only is slack important for technological innovation, but it must also be provided continuously over the organization's life cycle, including future expectations (Judge et al., 1997).

Human resources. Some researchers claim that human resources are the most important resources and are key factors of innovative organizations, as human beings are involved in the whole innovation process, and when encouraging and motivating them the company may draw from their collective wealth of knowledge (Kayabasi et al., 2013; López-Fernández et al., 2011; Steele and Murray, 2004). The benefits are better performance and better understanding of the market orientation, resulting in unique offering and having indirect effects on customer value (Paladino, 2007)

Innovative organizations make strategic choices based on human resources, and the agility and ability of employees to respond to a changing marketplace lies in the intellectual capital of a company's people. When the human resources are competitive, they can stretch the boundaries of competence into unknown or new areas. To accomplish such an extension, organizations must explicitly strive towards the attraction, development and retention of creative talent, where many innovation

champions must be identified, recruited, developed, trained, encouraged and acknowledged throughout the organization (Chadwick and Dabu, 2009), including by managerial and non-managerial personnel (Searle and Ball, 2003). Companies must ensure that this affirmation is developed across both vertical and horizontal levels within the organization and with partners (Estrada et al., 2013). Companies should also employ people who do not seem to fit and are prepared to take risks, however, with purpose of disrupting the status quo (Nanda and Singh, 2009; Steele and Murray, 2004), or at least securing access to people who have the most knowledge of the task and the technology required to ensure its effective completion, especially if being work on across different departments (Shipton et al., 2006). To some workers, self-managed teams may be seen as desirable grants of autonomy or another way for management to enforce a "speed up" scheme (Chadwick and Dabu, 2009), but it is likely that training or team motivation has to be designed in a specific way, as these teams may work more independently than the rest of firm's collaborative areas (Donate and Guadamillas, 2011).

Need. The need to innovate has been clearly articulated for centuries. Without new ideas implemented into innovations, the organization will be terminated in the long run (Dobni, 2006). With these new innovation projects, one challenge is to understand and identify unmet needs, which can be done in two ways specified by Farris and Lane (2005). First, one can identify significant macro changes in the larger environment to frame the big picture. Second, one can identify concrete opportunities through a designed macro-environmental change. As soon as an unmet need is identified, it must be addressed to become a business opportunity and to identify core benefit for the target market. From an R&D perspective, to maximize an R&D innovation contribution the opportunity has to match the companies wants and needs, as well as the context and customers (Bingham 2003).

Processes. The cyclic innovation model, based on collaboration and iteration, has emerged from linear processes over time. In it, there is a clear user and customer focus (Berkhout et al., 2006; Dobni, 2006). The aim of these processes are to interact with customers, co-suppliers and internal service providers, and to explore technological opportunities; to build customer knowledge, understanding the entire system including networks; and to interact and co-develop with customers and partners to comprehend, visualize, and deliver value propositions. Four specific phases in the innovation process are suggested by Bessant (2005): search, select, implement, and learn. These core activities do not take place in isolation, but are influenced by a set of contextual factors that can be classified under the headings of innovation strategy, innovative organization and innovation linkages. In highly innovative companies, ideas come from everywhere in the organization. Most of these companies possess early feasibility tests for ideas, by which they are tested. The evaluations are generally to identify innovative modifications to the existing ideas and to make sure that new ideas do not repeat mistakes made in the past. The reason is to ensure that knowledge and learning are not lost and to check the innovation's effectiveness. The potentials and disadvantages of the ideas are clearly defined. Evaluating ideas in a way that optimizes creativity is a delicate process, as it can both increase and harm creativity, self-confidence and performance (Nanda and Singh, 2009).

In extension of the innovation processes, several methods have emerged for their execution. The innovation cube is suggested by Narasimhalu (2005) to navigate through drivers, triggers and enablers for innovation to detect new opportunities and to define what innovation to aim for depending on circumstances and environment. Smith et al. (2012) suggests 10 steps when redesigning products: choose a target product, identify needs, choose reference products, identify components, build a component factor table, determine component factor weights, extract key components, identify conflicts, apply design principles, and verify results. Open innovation is suggested in all of the cyclic processes, but open innovation processes have both advantages and risks. The benefits are that they are faster and the potential risks are, for example, lack of coordination, mistrust and collaboration problems. The challenge for the management in the open innovation process is to determine the appropriate methods and practices for the utilization of external knowledge resources (Bergman et al., 2009). Collaborative networks offer one way to practice open innovation (Eschenbächer et al., 2011).

The operational work can be divided in two phases. In the early innovation phase brings the ideas into focus, and the later phase brings the implementation into focus; this latter phase is also where the financial risks are highest (Eschenbächer et al., 2011). Another practical approach to executing innovation work is to fail fast (i.e. to make mistakes early, learn from them, and try not to avoid failure. Instead, fall forward). Seven steps are suggested: First, decide what success and failure would look like before you launch initiative; second, convert assumptions into knowledge; third, be quick about it—fail fast; fourth, limit the downside risk—fail cheaply; fifth, limit uncertainty; sixth, build a culture that celebrates intelligent failure; and seventh, codify and share what you learned (Tahirsylaj, 2012). The fast-failure methodology is well known in software development by methods such as the scrum, which is an agile work method (Adkins, 2010). Due to the level of abstractness in innovation work, the visual design to envision processes acts as a knowledge agent in terms of "knowledge integrator" and "knowledge broker" to support innovation (Bertola and Teixeira, 2003). Technology is often used in a supportive role to ease various stages and remove the fuzziness of the innovation process (Smith et al., 2008), and rapid prototyping is used to speed up the actual innovation work, as rapid prototyping is beneficial for testing and evaluating ideas in early stages (Vashishtha et al., 2011). Both creativity and innovation processes are complex and are dependent on both individual and group efforts from divergence and convergence perspectives (Haner, 2005), but the most critical part in innovation work is finance. Another crucial aspect is that partnerships can be negatively affected due to institutional and regulatory factors, namely a lack of clear laws and rules regarding intellectual property (Chu and Andreassi, 2011).

Strategy. On the operational and managerial level, one suggested strategy is to apply is cooperation rather than competition. However the focus of the innovation work should be on the target market (Gibbert et al., 2002; Hine and Ryan, 1999). A company could develop innovative solutions on a local or a global market, but the circumstances may not remain the same and must be treated with respect to their fluctuations. This consideration means that both primary and secondary environmental factors should be considered in strategic decision-making and in improvements to dynamic capabilities (Kask, 2011).

3.1 Individual perspective

Awareness. A company's success relies on maintaining the awareness of what is happening outside the company if one wants to develop new products for new lines of business (Logman, 2007; West et al., 2004), where reflection is pointed out as a key factor for innovation. When it comes to detecting new opportunities, awareness of customers' perceptions of value is of importance, as it requires a focus on benefits and cost drivers, which could be used as impulses for innovation (Chari, 2011; Logman, 2007). According to West et al. (2004), it requires awareness and knowledge to identify suitable work tasks and to choose the right tool to use according to what kind of innovation opportunity one is looking for (e.g. to identify existing opportunities). Different tools, such as lateral thinking, metaphoric thinking, positive thinking, association trigger, capturing, interpreting dreams, pattern recognition or blue ocean strategies, give different results (Tan, 2013). Park (2005) comes to the conclusion that awareness of opportunities comes from an interaction between three individual components: the entrepreneur, including institutionalization alertness and knowledge development, embracing risk, driving growth and market-driven innovation culture; the knowledge and experience within the firm, which includes new markets, customer requirements and technological expertise; and technology, which includes external technology providers.

Vaghely (2008) explains that opportunity recognition is divided in two streams: cognitive psychology, where patterns detected from impressions are compared to the environment; and social constructionism or developmental psychology, where a trial-and-error-mentality is used to build knowledge. Both these streams are combined as a key to innovation in hands of entrepreneurs or companies. Nicolaou et al. (2009) claim that opportunity recognition is correlated with heritability and environmental factors, and Farris and Lane (2005) claim that opportunity identification as a skill can be learned. Another practical strategy to apply is to utilize aspects of SMEs' approach to the internet, where internalization management enables small companies to respond to the changing environment in an agile way (Abouzeedan et al., 2013).

Capabilities. Capability refers, in short description, to the deployment and reconfiguration of resources to improve productivity and achieve strategic goals (e.g. strategic innovation goals) (Camisón and Villar-López, 2012; Kindström et al., 2012), which are closely related to innovation and further on to an organization's performance (Yesil et al., 2013). As well, skills that support innovation can be honed or influenced by external factors (Bharadwaj and Menon, 2000). Technical capabilities are seen to be very important to innovation (Bossink, 2004; Manley, 2006; Cetindamar et al., 2009), as they refer to the ability to perform any relevant technical function or volume activity within the firm, including the ability to develop new products and processes and to operate facilities effectively (Camisón and Villar-López, 2012). From this perspective, Cetindamar et al. (2009) point this out as a matter of technology management, where different capabilities are required along a six-step-process, starting from strategy and ending in a developed product on the market. The task for technology management is to adjust tools and activities according to the processes and capabilities required. From a knowledge management perspective, Cepeda and Vera (2007) suggests that managers devote more attention to identifying important knowledge and knowledge gaps concerning capabilities,

followed by filling the identified gaps with new knowledge, resulting in improved capabilities. When handling capabilities strategically, Majumdar (1999) points out the risk of downsizing companies, with an understanding the result will be lost competences and capabilities in the company, affecting innovation in a negative way.

On the other hand, Camisón and Villar-López (2012) claim that non-technical capabilities (organizational capabilities) are equally important, as they refer to capabilities to implement new methodologies and processes and to establish knowledge of best practices. As such, personality traits for innovation become important (e.g. attraction to complexity, high energy, independence of judgment, intuition, self-confidence and ability to accommodate opposites). Furthermore, intelligence, knowledge, eagerness to learn, inquisitiveness, diversity, risk-taking and a strong desire to fulfill goals are also important (Nanda and Singh, 2009).

Dedication. Companies with a motivated workforce are able to recognize and solve current problems and bring solutions to the marketplace faster than their competitors (Hauschildt and Kirchman, 2001; McGurk and Baron, 2012; Yang et al., 2011). Employees motivation is a balance of not being bored by too little space or work not challenging enough and the opposite, a feeling of not having control (Nanda and Singh, 2009). Motivation usually comes from three sources: first, extrinsic factors (i.e. motivation that comes from outside a person and includes e.g. feedback or rewards for creative ideas) (Fairbank and Williams, 2001); the most commonly used extrinsic motivator is money (Bright and Godwin, 2010. Extrinsic motivation does not necessarily make employees passionate about their work and hence may hinder creativity in the long run (Amabile et al., 1996; Amabile, 1998; Amabile and Gryskiewicz, 1989; Ahmed, 1998b), Second are intrinsic factors (i.e. motivation that comes from a deep interest and involvement in the work, where the key is that employees are motivated by their interest and satisfaction in the work itself, and not by external pressures) (Amabile and Kramer, 2012; Bright and Godwin, 2010; Kathleen, 2012; Kayabasi et al., 2013). Some degree of pressure within the work environment has a positive influence on motivation as well, that is, if it is perceived as arising from the urgent, intellectually challenging nature of the problem itself (Amabile, 1988). Third are relational factors, (i.e. motivation coming from doing work because it provides value to others). Practical ways of getting buy-in—to engage and commit employees into innovation, and thereby put free time into work activities—include embracing the uncertainty embedded in innovation work (Kathleen, 2012; Newton, 1998), providing a long-term compensation plan, job security and timely feedback on performance (Manso, 2011), and educating employees with skills they can utilize from in their free time (Evans and Waite, 2010; Newton, 1998).

Empowerment. As demonstrated above, empowerment is related to autonomous work and freedom to work independently on work tasks. This freedom requires individual self-leadership, a process by which people learn to lead themselves with different focus for different phases in the innovation process. Fostering innovative behavior, self-leadership includes the ability to renew cognitive constructions, to create mental imaginary solutions and creative self-talk to achieve desired results (Carmeli and Weisberg, 2006).

Entre- / intrapreneurship. Entrepreneurial and intrapreneurial behaviors have positive effects on innovation within a company and contribute to maintaining a sustainable innovation system (Dalohoun et al., 2009). Significant characteristics include that these people are opportunity driven (Ardichvili et al., 2000; Dalohoun et al., 2009; Morris et al., 2006; Rigtering and Weitzel, 2013), take risks (Baucus et al., 2008; Chen, 2007; Rigtering and Weitzel, 2013), overcome obstacles (Lukes, 2012), and break rules and standard operating procedures (Baucus et al., 2008).

However, entrepreneurs and intrapreneurs do not wait for opportunities to be found; they are made or recognized (Ardichvili et al., 2000, Dalohoun et al., 2009; Rigtering and Weitzel, 2013). Even though entrepreneurs and intrapreneurs challenge management and rules, management must be aware of and support this behavior (Baucus et al., 2008; Lukes, 2012; Vale and Addison, 2002), providing freedom "within a framework" to detect opportunities and act proactively (Chen, 2007; Lumpkin and Dess, 2001). Otherwise, these people may find another job (Morris et al., 2006).

Incentives. Building an economic model of innovation that does justice to the various aspects is, quite obviously, an impossible task (Overvest and Veldman, 2008), and incentives are a highly debated area, where research shows both positive and negative effects on motivation for innovation. Incentives include both financial compensation and nonfinancial intrinsic and extrinsic incentives, but they have different effects on innovation (Chen et al., 2012), where the structure of a firm's human resource management HRM system itself functions as a nonfinancial motivation, and compensation may help to shape employee behaviors (Chadwick and Dabu, 2009).

Innovative companies rely on personalized intrinsic rewards, where less innovative companies place almost exclusive emphasis on extrinsic awards (Nanda and Singh, 2009). Intrinsic rewards are claimed to be more motivating to innovation than extrinsic rewards, referring to job security, tolerance for early failure and timely feedback on performance (De Jong and Den Hartog, 2007; Manso, 2011; Nanda and Singh, 2009; Stempfle, 2011), having control over the small part with which they are closely involved (Cooper 2005). Extrinsic incentives have negative effects on innovation as they tend to make people risk-averse and foster the expectation that they will be compensated for every action they take (Chen et al., 2012; Judge et al., 1997, Nanda and Singh, 2009). They also tend to involve overinvestment in projects (Inderst and Klein, 2007; Inderst, 2009) and manipulation of bonuses (Holthausen et al., 1994). However, extrinsic incentives can be highly motivating if they are carefully combined with strict wage rules (Haucap and Wey, 2004), support company goals, are fair and understandable, relate to performance and expected behavior, and support creativity and personal initiative (Lukes, 2012). If employees are rewarded only for success, they will go for the "low-hanging fruits" and pursue incremental innovation that is almost certain to produce results (Stempfle, 2011; Tushman and Nadler, 1986). Hence, the best effects of incentives are the ones that are connected to performance and not activity (Sheikh, 2012). Prize awards as incentives have been used to motivate individuals, groups, and communities to accomplish diverse types of goals, but established companies tend to not participate in them because of varying levels of uncertainty and because resources spent on competition do not compensate for the associated price (Kay, 2011). When rewards are based on group effort, they support

team spirit and create a climate in which individuals and teams cooperate and help each other with new ideas (Drake et al., 2001; Lukes, 2012,) but when employees face tournament incentives, they tend to maximize their own profits, resulting in lower firm profit (Drake et al., 2001).

Short-term incentives are associated with incremental innovation, and long-term incentives are associated with radical innovation, but companies use both systems when designing compensation systems (Cabrales et al., 2008). However, long-term incentives have positive effects on innovation (Fu, 2012), and companies that focus on long-term incentives are more successful (Lerner and Wulf, 2007); in these cases, ownership in IP (Liu, 2013) or stock bonuses (Chen et al., 2012; Sheikh, 2012, Manso, 2011) are commonly used as incentives. Factors that stimulate innovation at some point during an organization's development actually hinder it in other ways. For example, in late-stage firms, incentives and innovation are quite highly correlated, and centralized leadership may contribute to innovativeness in a firm's early stages, but not in later stages (Koberg et al., 1996).

Knowledge. Appropriate knowledge for innovation has become more and more important (Francois et al., 2002). Intangible assets are the lifeblood of knowledge-intensive industries where the new value added is disproportionately based on specialized, non-repetitious activities recognized as central to sustaining the competitiveness of firms and innovation systems (Kramer et al., 2011), and this type of asset has become one of the most strategically resources for successful innovation as a result of increased knowledge-based competition (Bucic, 2012). Organizational knowledge emerges when sense making, knowledge creation and decision making are connected to each other, and when a deliberate and frequent flow of information is applied to glue the three areas together, the result is, for example, innovation (Choo, 2001). However, employees need to be trained and educated before they can have a positive impact on the innovation process (Smith et al., 2008), but there is also a need for competence in the hiring of qualified personnel to participate in innovative projects (Francois et al., 2002) and use knowledge in an appropriate way, as knowledge itself does not generate any value (Hung et al., 2010). One practical way of using knowledge is to focus on the different stakeholders' changing interests during an innovation project, since knowing the nature of the interests and perceptions of the involved parties at a certain critical point leads to possible ways of engaging, which in turn may help to create a satisfying outcome from the innovation process (Weisenfeld, 2003). Another way of using knowledge is to bridge the diverse knowledge of members in a multifunctional team so knowledge gaps that are too large do not open (Jablokow and Booth, 2006).

Knowledge networks require direct and intense interaction between individuals with relevant knowledge and expertise, enabled within the structure of a socially embedded network. Tacit knowledge is often referred to as the "know-how" that individuals acquire through experience or learned from behavior in a collective context and is more slowly transferred through boundaries than explicit knowledge. Despite the understanding of interactive learning as core of innovation, tacit knowledge is often so embedded within the individual that she may be unaware of its importance (Dooley et al., 2013). The input perspective is dependent on the individual and enterprise's ability to know where to acquire tacit knowledge, as well as the enterprise's ability to

support this knowledge. A key knowledge action is therefore to obtain tacit knowledge from people who are not necessarily only employees (internal to the enterprise), but can also be sources external to the enterprise, such as clients, suppliers or competitors. The output perspective is dependent on the individual's ability to convert the conveyed tacit knowledge into his or her own tacit knowledge. The key knowledge action is therefore to transform individual tacit knowledge into new, shared tacit knowledge. This process is possible only through frequent face-to-face contact between parties, which is dependent on geographical and social closeness. There is also a need for intensive communication in both the short term and the long term (Esterhuizen et al., 2012). The key to obtaining a long-term competitive advantage is not to be found in the administration of existing knowledge, but in the ability to constantly generate new knowledge. The process of generating knowledge can be categorized into four different knowledge-creation processes, as identified by Nonaka and Takeuchi (1995): socialization, externalization, combination and internalization. The literature provides a strong basis for the argument that knowledge management, and more specifically knowledge creation processes, could be used to improve an enterprise's innovation capability maturity (Esterhuizen et al., 2012).

Knowledge management. Knowledge management (KM) is defined as the formalized approach to managing the creation, transfer, retention, and utilization of an enterprise's explicit and tacit knowledge assets (Amalia and Nugroho, 2011; Cepeda and Vera 2007; Palacios et al., 2009; Plessis, 2007), and the term refers to intellectual capital (Masoulas, 1998; Plessis, 2007) including human capital, structural capital, and relational capital (Gaimon and Bailey, 2013; Mentzas, 2004). Knowledge management also includes innovation capital, which serves the purpose of increasing process management skills, facilitating collaboration and assisting in building competencies (Plessis, 2007; Shang et al., 2009), where important action to bring into the innovation capital of KM (i.e. innovation processes) are search, capture, articulate, contextualize, apply, evaluate, support and re-innovate (Tranfield et al., 2003). Organizations with well-developed knowledge management practices and behaviors are more innovative (Kamhawi, 2012; Liao and Wu, 2010), more competitive and earn more money (Loan, 2006; McGurk and Baron, 2012), and a well-developed KM strategy is considered one reason for such success (López-Nicolás and Merono-Cerdán, 2011).

KM is built on two dimensions, according to Palacios et al. (2009): principles and practices. Principles, referring to a higher level of research that is more abstract or related to ideas and practices, refer to tools and techniques to be used (Rogers, 1998) for meaningful learning (e.g. customer knowledge management to collect valuable information from the customers) (Coviello and Joseph, 2012; Gibbert et al., 2002; Hidalgo and Albors, 2008; Johannessen, 2008; McGurk and Baron, 2012), to establish measurement tools for performance (Chourides et al., 2003) and to identify gaps organizations' internal and external knowledge by focusing on people, processes and technology (Maqsood and Finegan, 2009).

Both exploration and exploitation have significant effects on innovation, and leaders play an important role in establishing the organizational conditions and infrastructure that facilitates KM (Donate and Guadamillas, 2011), such as ICT (Cormican and O'Sullivan, 2000; López-Nicolás and Merono-Cerdán, 2011; Smith et al., 2008). One

way of reducing costly slack in production and providing slack to create innovations is to combine TQM with KM (Honarpour et al., 2012). By extension, KM must also be adjusted the company´s size, accepting that small companies turn to their networks outward to manage innovation challenges, and large companies find ways to make their organizations feel smaller by creating project-based units (Andriopoulos and Lewis, 2010). This description aligns with agile organizations that have the ability to constantly sense competitive opportunities and threats and respond through innovative solutions in the form of, for instance, new products and processes by having the ability to quickly arrange the required knowledge and assets to innovate and react to a changing environment (Kamhawi, 2012)

Effective KM also contributes to organizational learning, which forms a bridge between knowledge management and organizational innovation (Liao and Wu, 2010). The most competitive organizations are those with the ability to learn (i.e. to incorporate learning processes and knowledge creation into everyday operations and management where much of the learning involves converting knowledge from tacit to explicit forms) (Heffner and Sharif, 2008). As knowledge has been created, it must also be shared to become useful to the organization (McAdam, 2000), and this sharing is enabled thorough strategy and leadership, corporate culture, people, and information technology (Yesil et al., 2013), along with how knowledge flows in, across and out of the organization (McGurk and Baron, 2012).

Mind-set. People deal with the uncertainty and risk on a daily basis, but understandings of whatever uncertainty or risk is dangerous or is needed to be avoided or eliminated are personal. These understandings are powerful determinants for the tolerance of risk and uncertainty, both collectively and individually, but they are constructed, which makes risk and uncertainty neither objective nor subjective. Communication based on experience is commonly used to explore what affect a certain risk or uncertainty will have in a specific situation, potentially resulting in creative solutions. Because of their subjective nature, however, perceptions of risk and uncertainty are bound to the particular experience of an individual or of a group of people (Anderson, 2011). When a person is slightly biased in a pro-innovation way, this person may have a considerable performance advantage in many circumstances, for instance, in medium to highly complex, constant environments, when long-term considerations matter, and when firms search locally. However, a pro-innovation bias that is too distinct will make the search process inefficient and result in an exploration trap (Baumann and Martignoni, 2011). One risk that employees fear is to make fools out of themselves, and this fear relates to an organization's tolerance for trying out ideas that may fail, which makes employees unwilling to try and innovate or engage in activities apart from their day-to-day work. This problem may be overcome by spelling out the risk and what consequences an initiative will have (Nanda and Singh, 2009).

Innovation is a highly sophisticated knowledge and cognitive process. One of the key insights of an "enabling approach to innovation" is that it starts with a process of deep observation, investigation and comprehension of the object of innovation and its systemic context. To succeed, though, one must be active in the process of seeking the newness (Peschl and Fundneider, 2012).

A positive attitude influences innovation as well, since a humorous atmosphere and, active celebration of success, and verification stories of success throughout the organization motivate employees and team work (Nanda and Singh, 2009). By extension, playing at work may stretch network boundaries to both individuals and digital equipment (Brooks and Bowker, 2011).

The creation of self-efficacy may increase one's motivation, creating greater eagerness to pursue individual ideas and more effective use of cognitive resources and having a positive effect on innovative behavior and climate (Denti and Hemlin, 2012). The same is true when building up a "we-can-do-it" mind-set (Gil et al., 2005). Self-efficacy can be built through positive feedback on conducted work; even though the work itself may be average, the positive feedback results in greater creativity and problem-solving skills. As a result, personal initiative is taken in terms of individual and team engagement in work tasks beyond the work contract, but successful team work is characterized by trust, vision, the aim of excellence, participative safety, and support for innovation, which together are likely to secure high levels of innovation (Denti and Hemlin, 2012; Kianto, 2011). However, innovation is also the art of individuals who triumph over the status quo, which includes asking questions, teaching oneself new skills, taking action, adapting and collaborating, and believing in strong results (Nanda and Singh, 2009). To make this happen, the individual must have the willingness to conduct these activities (López-Fernández et al., 2011), and this willingness is fostered by organizational culture (Smith et al. 2008).

Time. Time has been discussed in two perspectives when developing innovative and competitive products. One perspective is to use time as a key component within the product itself (i.e. to save time by reducing steps in manufacturing processes or organizing sites strategically to reduce the shipping time of components or products) (Fields, 2006). The other perspective refers to actual time for innovation work. To foster a creative milieu, which is important for innovation, one must not only have information but also enough time to engage, process and reflect on that information at all stages of a project (Anderson, 2011, 2013; Smith et al., 2008). For example, available time for idea development or technical solutions is of essence for innovation work. The more time a designer spends on defining, framing and understanding the problem, the more likely it is that a creative result will be achieved (Ross et al., 2012).

Table 5. The table demonstrates the identified innovation enablers and articles referring to them.

#	Innovation enabler in articles	Articles per perspective, including doublets			Articles referring to each innovation enabler
		Org.	Team	Ind.	
1	Collaboration				39
2	Management				37
3	Knowledge management				29
4	Climate				20
5	Incentives				20
6	Culture				19
7	Dedication				16
8	Processes				15
9	Education				12
10	Knowledge				11
11	Capabilities				10
12	Mind-set				10
13	Human recourse				10
14	Awareness				9
15	Empowerment				9
16	Entre-/intra-preneurship				9
17	Strategy				9
18	Economy				8
19	Time				7
20	Need				3
	Total				302

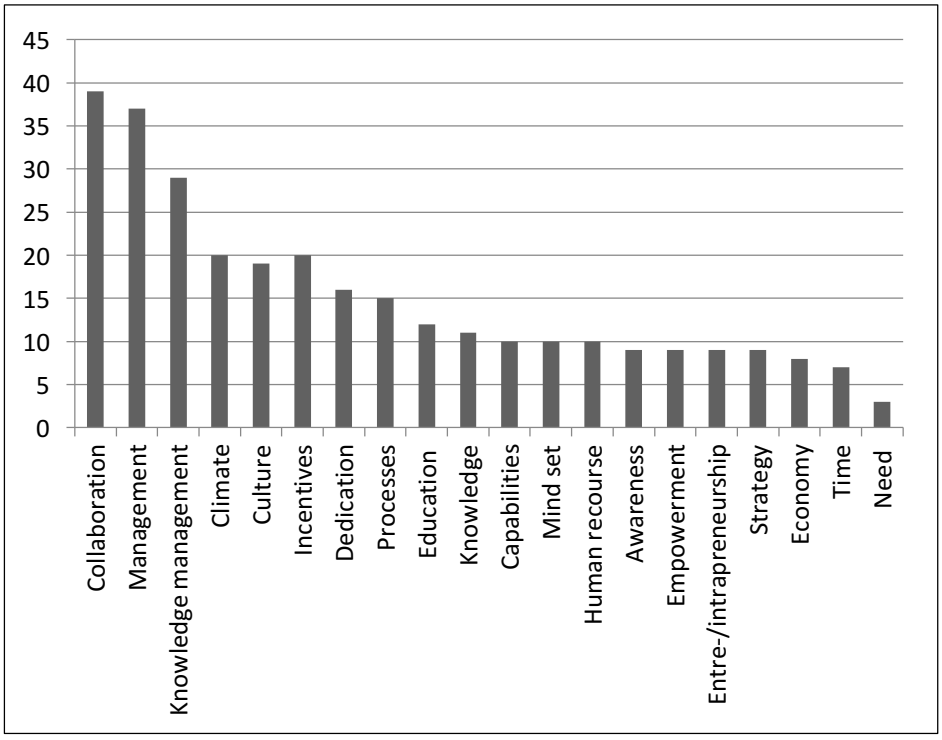


Fig. 1 - The figure demonstrates articles referring to different innovation enablers.

4 Conclusion and future work

The collected data were clustered into the categories of innovation enablers that enable innovation team to conduct innovation work. Out of 211 identified articles, 47 contributed with data to more than one innovation enabler, as seen in Table 5. The identified enablers were organized by levels: organizational, team, and individual. In total, 20 innovation enablers were detected. Significant results were that 39 articles referred to "collaboration" as an innovation enabler, and three articles referred to "need" as an innovation enabler. As mentioned in the research design, only articles where the author(s) provided content to the innovation enabler were collected, so if there was no explanation from which an action could be taken, the article was rejected. The findings revealed a complex picture in which descriptions of the innovation enablers overlap and intervene with each other, making them dependent on each other, to some extent. For example, management as an innovation enabler is to a certain extent one of the most powerful elements, as managers may terminate an innovation team on an official basis; on the other hand, management is not important at all, as an innovation team's dedication may have the power to move mountains and may continue working regardless of management's approval or support. Another example is "climate," concerning which the researchers include factors such as leadership, time for innovation, and so forth, and as such refer to "management." However, within this review, the thematic analysis has focused on factors that enable

innovation teams' innovation work, by which the author could offer content to the enabler.

Additionally, this review also focuses on innovation enablers from the innovation team's point of view. Based on the results, a list of innovation enablers is suggested where the main keywords in each one of the innovation enablers are made explicit out. These innovation enablers too overlap and depend on each other, but the list provides an understanding and holistic overview of what factors enable innovation teams to conduct innovation work.

Table 7. The table demonstrates the identified innovation enablers and keywords that describe their content.

Innovation enablers [alphabetical order]
Awareness (E.g. ability to "see" invisible or unrevealed innovation related opportunities)
Capabilities (E.g. skills related to management or work in an innovation project)
Climate (E.g. OK to fail-, let's try-, let's do-mentality in work environment)
Collaboration (E.g. x-functional teams, collaboration between departments, suppliers and customers, open innovation, networks)
Culture (E.g. norms and invisible rules within the organization, "this is how we do it here"-mentality)
Dedication (E.g. factors making one feel dedicated, motivated or stimulated to work in innovation projects)
Economy (E.g. budget, non-monetary resources)
Education (E.g. innovation-related training in theory and practice)
Empowerment (E.g. trust to take one's own decisions regarding resources to spend on tasks to do, autonomy, interdependence)
Entre- / intrapreneurship (E.g. doers that make things happen)
Human resources (E.g. access to other colleagues that could contribute to innovation project, sharing competence and contributing to reduce bottle necks.)
Incentives (E.g. monetary and non-monetary rewards)
Knowledge (E.g. regarding innovation and expertise in an innovation project topic)
Knowledge management (E.g. knowledge in how to use knowledge or how to fill knowledge gaps related to the innovation project)
Management (E.g. project managers, leadership, management support related to the innovation project)
Mind-set (E.g. self-confidence "I can," contributing "I share," want-to develop company, pro-innovation bias "I like," free-will "I want to")
Need (E.g. explicit and clarified need to solve for customer, organization… The "why we should do this")
Processes (E.g. innovation process, models and best practice that guides from idea to product

on market)
Strategy (E.g. directions in customer segment, areas, geographical markets, level of novelty on new products and technology to use or develop)
Time (E.g. time dedicated or allocated to the innovation project)

This review the area of innovation enablers from the perspective of innovation teams led the research to include also the organizational and members' perspective of an innovation team as well. This research demonstrates that innovation enablers are difficult to separate, as they interact with each other. However, 20 different innovation enablers were identified as key factors for innovation teams' innovation work, as demonstrated in Table 7.

Contribution to prior research. This research contributes to prior research by focusing on innovation enablers for innovation teams to conduct innovation work. The main contribution is to provide a holistic picture through which the scattered research field is collected, including the context of the innovation team: the organizational and team members' perspectives. Unlike many other reviews, it contributes by not only reviewing the research and identifying innovation enablers in a bullet-point list, but by also providing descriptions of what the innovation enabler is based on, making it usable for further research and practical application.

Practical applications of the results. Suggested practical use of the identified innovation enablers include, for example, the identification of innovation team's need when conducting innovation work, using the listed of innovation enablers as a checklist to fill gaps of important innovation enablers by identifying what enablers are fulfilled or not. Thus, Table 7 represents a practical template to be used as a checklist or toolkit.

Limitations within this review. As pointed out above, an innovation team admits of consideration vis a vis three different characteristics, each with a direct impact on the innovation team. However, there are other factors as well, such as policies, political directions and regional factors that affect an innovation team's innovation work directly or indirectly, but these aspects have been excluded from this review. The selected papers were identified using a specific selection methodology based on synonyms used in combination to cover a broad area of research, where papers with relevant content may not have been detected due to the author's use of other terminology than that deployed in this research, which may then affect the results.

Suggested future research. This review demonstrates innovation enablers that enable innovation teams to conduct innovation work. However, the review does not demonstrate to what degree they enable an innovation team to conduct innovation work or to what degree they are important to an innovation team. Based on this review, one cannot claim that one innovation enabler is more important than another one; rather, the review serves a greater understanding of what factors prior research suggest to be enablers of success for innovation teams. Therefore, suggestions of future research are to study the importance of innovation enablers to identify the degree to which they are important or not to innovation teams when conducting innovation work, to identify what innovation enablers are most important relative to the others, and to determine whether the importance of innovation enablers varies

across time in an ongoing innovation project. The contribution would offer an even deeper understanding of innovation enablers in innovation work conducted by innovation teams. Further, this research could be used as a platform to build on for further reviews with the same approach, since the field is constantly growing as new papers and reviews are published.

6 References

Aagaard, A. & Gertsen, F. (2011) Supporting Radical Front End Innovation: Perceived Key Factors of Pharmaceutical Innovation. *Creativity and Innovation Management*, 20(4), 330-346.

Abouzeedan, A. & Klofsten, M., Hedner, T. (2013) Internetization Management as a Facilitator for Managing Innovation in High-Technology Smaller Firms. *Global Business Review*, (14(1), 121-136.

Adamides, E.A. & Karacapilidis, N. (2006) Information technology support for the knowledge and social processes of innovation management. *Technovation*, 26, 50-59.

Adams, R, Bessant, J. & Phelps, R. (2006), Innovation management measurement: A review. *International Journal of Management Reviews*, 8(21), 21-47.

Adkins, L. (2010). *Coaching Agile Teams: A Companion for ScrumMasters, Agile Coaches, and Project Managers in Transition*. Massachusetts, Courier.

Ahmed, P.K. (1998b). Culture and climate for innovation. *European Journal of Innovation Management*, 1(1), 30-43.

Ahuja, G., Lampert, C.M. & Tandon, V. (2008) Moving Beyond Schumpeter: Management Research on the Determinants of Technological Innovation. *The Academy of Management Annals*, 2(1), 1-98

Akgün, A.E., Byrne, J.C., Lynn, G.S. & Keskin, H. (2007) Team stressors, management support, and project and process outcomes in new product development projects. *Technovation*, 27, 628-639.

Amabile, T.M. (1988) A model of creativity and innovation in organizations. *Research in organizational behavior*, 10, 123-167.

Amabile, T.M. & Gryskiewicz, N. (1989) The Creative Environment Scales: The Work Environment Inventory. *Creativity Research Journal*, 2, 231-254.

Amabile, T.M. & Kramer, S. (2012) How leaders kill meaning at work. *The McKinsey Quarterly*, 1, 124-131.

Amabile, T.M., Conti, R., Coon, H., Lazenby, J. & Herron, M. (1996) Assessing the work environment for creativity. *Academy of Management Journal*, 39, 1154-1184.

Amabile, T.M. (1998) How to kill creativity. *Harvard Business Review*, September-October 1998, 76-87.

Amalia, M. & Nugroho, Y. (2011) An innovation perspective of knowledge management in a multinational subsidiary. *Journal of Knowledge Management*. 15(1), 71-87.

Anderson, T.D. (2011) Beyond eureka moments: supporting the invisible work of creativity and innovation. *Information Research*, 16(1).

Anderson, T.D. (2013) The 4Ps of innovation culture: conceptions of creatively engaging with information. *Information Research*, 18(3).

Anderson, N.R. & West, M.A. (1998) Measuring climate for work group innovation: development and validation of the team climate inventory. *Journal of Organizational Behavior*, 19, 235-258.

Andersson, R. (1996) Uppfinnarboken - Om uppfinnandets innersta väsen (in Swedish). Malmö, Lieber-Hermods.

Andriopoulos, C. & Lewis, M.W. (2010) Managing Innovation Paradoxes: Ambidexterity Lessons from Leading Product Design Companies. *Long Range Planning*, 43, 104-122.

Anghern, A. & Nabeth, T. (1997) Leveraging Emerging Technologies in Management Education: Research and Experiences. *European Management Journal*, 15(3), 275-285.

Ardichvili, A., Cardozo, R. & Ray, S. (2000) A theory of entrepreneurial opportunity identification and development. *Journal of Business Venturing*, 18, 105–123.

Arranz, N. & De Arroyabe J.C.F. (2012) Can innovation network projects result in efficient performance? *Technological Forecasting & Social Change*, 79, 485–497.

Backström, T. & Olson, B.K. (2010) Kaikaku - a complement to emergence based development. Paper presented at the first ICDC Conference Kobe, Japan.

Backström, T., Wilhelmson, L., Åteg, M., Olson, B.K., Moström Åberg, M. (2011), *The Role of Manager in the Post-Industrial Work System. In: Studies in industrial renewal*, edited by Segelod, E., Berglund. K., Bjurström, E., Dahlquist, E., Hallén, L., Johansson, L. Eskilstuna, Mdh Repro, 215-227.

Balsamo, T.J., Goodrich, N.E., Lee, J.M, Morse, T.F. & Roberts, D.A. (2008) *Identify your innovation enablers and inhibitors*. Industrial Research Institute, 23-33.

Baucus, M.S., Norton Jr, W. I., Baucus, D.A. & Human, S.E. (2008) Fostering Creativity and Innovation without Encouraging Unethical Behavior. *Journal of Business Ethics*, 81,97-115.

Baumann, O. & Martignoni, D. (2011) Evaluating the New: The Contingent Value of a Pro-Innovation Bias. *Schmalenbach Business Review*, 63, 393-415.

Baxter, M. (2002) *Product Design*. Cheltenham, Nelson Thornes Ltd.

Berghman, L., Matthyssens, P., Streukens, S. & Vandenbempt, K. (2013) Deliberate Learning Mechanisms for Stimulating Strategic Innovation Capacity. *Long Range Planning*, 46, 39-71.

Bergman, J., Jantunen, A. & Saksa, J-M. (2009) Enabling Open Innovation Process Through Interactive Methods: Scenarios And Group Decision Support Systems. *International Journal of Innovation Management*, 13(1), 139-156.

Berkhout, A. J., Hartmann, D., Van der Duin, P. & Ortt, R. (2006) Innovating the innovation process. *Int. J. Technology Management*, 34(3/4), 390-404.

Bessant, J. (2005) Enabling Continuous and Discontinuous Innovation: Learning

From the Private Sector. *Public Money & Management*, January.

Bertola, P. & Teixeira, J.C. (2003) Design as a knowledge agent How design as a knowledge process is embedded into organizations to foster innovation. *Design Studies*, 24(2), 181-194.

Bharadwaj, S. A Menon, A. (2000) Making Innovation Happen in Organizations: Individual Creativity Mechanisms, Organizational Creativity Mechanisms or Both? *Journal of Product Innovation Management*, 17, 424-434.

Billett, S. (2001) Learning through work: workplace affordances and individual engagement. *Journal of Workplace Learning*, 13(5), 209-214.

Birkinshaw, J. & Mol, M. (2006) How Management Innovation Happens. *MIT Sloan Management Review*, 47(4), 80-89.

Birkinshaw, J., Bessant., J. & Delbridge, R. (2007) Finding, Forming, and Performing: Creating Networks For Discontinuous Innovation. *California Management Review*, 49(3), 67-84.

Bossink, B. (2004) Managing Drivers of Innovation in Construction Networks. *Journal of Construction Engineering and Management*, 337-345.

Bowonder, B., Dambal, A., Kumar, S. & Shirodkar, A. (2010) Innovation Strategies for Creating Competitive Advantage. *Research Technology Management*, 19-32.

Boyatzis, R.E. (1998) *Transforming Qualitative Information: Thematic analysis and code development*. USA, SAGE Publications Inc.

Bozeman, B. (2000) Technology transfer and public policy: a review of research and theory. *Research Policy*, 29, 627-655.

Brennan, A. & Dooley, L. (2005) Networked creativity: a structured management framework for simulating innovation. *Technovation* 25, 1388-1399.

Bright, D.S. & Godwin, L.N. (2010) Encouraging Social Innovation in Global Organizations: Integrating Planned and Emergent Approaches. *Journal of Asia-Pacific Business*, 11, 179-196.

Brooks, L.J., & Bowker, G. (2011) Playing at Work: Understanding the Future of Work Practices at the Institute for the Future. Information. *Communication & Society*, 5(1), 109-136.

Brown, C. (2005) Empowering innovation: extending services regionally. *World Patent Information*, 27, 37–41.

Bucic, t. & Ngo, l.v. (2012) Examining drivers of collaborative inbound open innovation: empirical evidence from Australian firms. *International Journal of Innovation Management*, 16(4).

Bush, J.B.Jr. & Frohman, A.L. (1991) Communication in a "Network" Organisation.

Cabrales, À.L., Medina, C.C., Lavado, A.C. & Cabrera, R.V. (2008) Managing functional diversity, risk taking and incentives for teams to achieve radical innovations. *R&D Management*, 38(1), 35-50.

Camisón, C. & Villar-López, A. (2012) Organizational innovation as an enabler of technological innovation capabilities and firm performance. *Journal of Business Research*, 67, 2891-2902.

Carmeli, A.R.M & Weisberg, J. (2006),"Self-leadership skills and innovative behavior at work", *International Journal of Manpower*, Vol. 27 Iss 1 pp. 75 – 90.

Cetindamar, D., Phaal, R. & Probert, D. (2009) Understanding technology management as a dynamic capability: A framework for technology management activities. *Technovation*, 29, 237-246.

Cepeda, G. & Vera, D. (2007) Dynamic capabilities and operational capabilities: A knowledge management perspective. *Journal of Business Research*, 60, 426-437.

Černe, M., Jaklič, M. & Škerlavaj, M. (2013) Decoupling management and technological innovations: Resolving the individualism–collectivism controversy. *Journal of International Management*, 19, 103-117.

Chadwick, C. & Dabu, A. (2009) Human Resources, Human Resource Management, and the Competitive Advantage of Firms: Toward a More Comprehensive Model of Causal Linkages. *Organization Science*, 20(1), 253-272.

Chari, V.V., Golosov, M. & Tsyvinski, A. (2011) Prizes and patents: Using market signals to provide incentives for innovations. *Journal of Economic Theory*, 147, 781-801.

Chen, M.Y-C., Lin, C.Y-Y., Lin, H-E. & Mc.Donough, E.F. (2012) Does transformational leadership facilitate technological innovation? The moderating roles of innovative culture and incentive compensation. *Asia Pac Journal Management*, 29, 239–264.

Chen, M-H. (2007) Entrepreneurial Leadership and New Ventures: Creativity in Entrepreneurial Teams. *Entrepreneurial Leadership and New Ventures*, 16(3), 239-249.

Cheng, C.C., Chen, J-S. & Tsou, H.T. (2012) Market-creating service innovation: verification and its associations with new service development and customer involvement. *Journal of Services Marketing*, 26(6), 444–457.

Choo, C.W. (2001) The knowing organization as learning organization. Education + Training, 43(4/5), 197-205.

Chou, A.Y. & Chou, D.C. (2011) Course Management Systems and Blended Learning: An Innovative Learning Approach. *Decision Sciences Journal of Innovative Education*, 9(3), 463-484.

Chourides, P., Longbottom, D. & Murphy, W. (2003) Excellence in knowledge management: an empirical study to identify critical factors and performance measures. *Measuring Business Excellence*, 7(2) 29-45.

Chu, D. & Andreassi, T. (2011) Management of technological innovation. Case studies in biotechnology companies in Brazil. Management Research: *The Journal of the Iberoamerican Academy of Management*, 9(1), 7-31.

Clark, D. (2012) Innovation Management in SMEs: Active Innovators in New Zeeland. *Journal of Small Business and Entrepreneurship*, 23(4), 601-619

Claver, E., Llopis, J., Garcia, D. & Molina, H. (1998) Organizational Culture for Innovation and New Technological Behavior. *The Journal of High Technology*

Management Research, 9(1), 55-68.

Cobo, C. (2013) Mechanisms to identify and study the demand for innovation skills in world-renowned organizations. *On The Horizon*, 21(2), 96-106.

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

Cooper, P. (2005) A study of innovators' experience of new product innovation in organisations. *R&D Management*, 35(5), 525-533.

Cooper, R.G. (2013) Where Are All the Breakthrough New Products? Using Portfolio Management to Boost Innovation. *Research-Technology Management*. 25-33

Cormican, K. & O'Sullivan, D. (2000) *A Collaborative Knowledge Management Tool for Product Innovation. In: The managing innovative manufacturing 2000 Conference*, July 17th-19th, Birmingham, UK.

Coviello, N.E. & Joseph, R.M. (2012) Creating Major Innovations with Customers: insights from Smali and Young Technology Firms. *Journal of Marketing*, 76, 87-104.

Crespell, P. & Hansen, E. (2008) Managing for Innovation: Insights into a successful company. *Forest Products Journal*, 58(9), 6-17.

Dalohoun, D.N, Hall, A., van Mele, P. (2009) Entrepreneurship as driver of a 'self-organizing system of innovation': the case of NERICA in Benin. International *Journal of Technology Management and Sustainable Development*, 8(2), 87-101.

De Jong, J.P.J & Den Hartog, D.N (2007),"How leaders influence employees' innovative behaviour", *European Journal of Innovation Management*, Vol. 10, 41 – 64.

De Jong, J.P.J. & Vermeulen, P.A.M. (2003) Organizing successful new service development: a literature review. *Management Decision*, 41(9), 844-858.

Denning, S. (2011) Reinventing management: the practices that enable continuous innovation. *Strategy & Leadership*, 39(3), 16-24.

Denti, L. & Hemlin, S. (2012) Leadership and Innovation in Organizations: A Systematic Review of Factors That Mediate or Moderate the Relationship. *International Journal of Innovation Management*, 16(3).

Dew, R. & Hearn, G. (2009). A new model of the learning process for innovation teams: Networked nominal pairs. *International Journal of Innovation Management*, 13(4), 521-535.

Dobni, C.B. (2006) The innovation blueprint. *Business Horizons*, 49, 329-339.

Donate, M.J. & Guadamillas, F. (2011) Organizational factors to support knowledge management and innovation. *Journal of Knowledge Management*, 15(6), 890-914.

Dooley, L., Cormican, K., Wreath, S. & O'Sullivan, D. (2000) Supporting Systems Innovation. *International Journal of Innovation Management*, 4(3), 277-297.

Dooley, L,. Kirk, D. & Philpott, K. (2013) Nurturing life-science knowledge discovery: managing multi-organization networks. *Production Planning & Control*, 24(2-3), 195-207.

Drake, A., Haka, S.F. & Ravenscroft, S.P. (2001) An ABC Simulation Focusing on Incentives and Innovation. *Accounting Education*, 16(3), 443-471.

Du Chatenier, E., Verstegen, J.A.A.M., Biemans, H.J.A., Mulder, M. & Omta, O. 2009 The Challenges of Collaborative Knowledge Creation in Open Innovation Teams. *Human Resource Development Review*, 350-381.

Du Plessis, M. (2007) The role of knowledge management in innovation. *Journal of Knowledge Management*, 11(4), 20-29.

Ekvall, G. (1996) Organizational climate for creativity and innovation. *European Journal of Work and Organizational Psychology*, 5, 105–124.

Ellström, E., Ekholm, B. & Ellström, P.E. (2007) Two types of learning environment Enabling and constraining a study of care work. *Journal of Workplace Learning*, 20(2), 84-97.

Eschenbächer, J., Seifert, M. & Thoben, K-D. (2011) Improving distributed innovation processes in virtual organisations through the evaluation of collaboration intensities. *Production Planning & Control*, 22(5-6), 473-487.

Eschenbaecher, J. & Graser, F. (2011) Managing And Optimizing Innovation Processes In Collaborative And Value Creating Networks. *International Journal of Innovation and Technology Management*, 8(3), 373-391.

Esterhuizen, D., Schutte, C.S.L. & Toit, A.S.A. (2012) Knowledge creation processes as critical enablers for innovation. *International Journal of Information Management*, 32, 354-364.

Estrada, I., Martin-Cruz, N. & Pérez-Santana, P. (2013) Multi-partner alliance teams for product innovation: The role of human resource management fit. *Management, policy & practice*, 15(2), 161-169.

Evans, K. & Waite, E. (2010) Stimulating the innovation potential of 'routine' workers through workplace learning. Transfer: *European Review of Labour and Research*, 16(2) 243–258.

Fairbank, J.F. & Williams, S.D. (2001) Leadership And Innovation In Organizations: A Systematic Review Of Factors That Mediate Or Moderate The Relationship. *Creativity and Innovation Management*, 10(2), 68-74.

Farris, J. & Lane, P. (2005) *Work in Progress - Teaching Opportunity Identification*. 35th ASEE/IEEE Frontiers in Education Conference.

Fields, G. (2006) Innovation, Time, and Territory: Space and the Business Organization of Dell Computer. *Economic Geography*, 82(2) 119-146.

Ford, D. & Paladino, A. (2013) Enabling Innovation through Strategic Synergies. *Journal of Product Innovation Management*, 30(6), 1058–1072.

Francois, J.P., Favre, F. & Negassi, S. (2002) Competence and Organization: Two Drivers of Innovation. *Economics of Innovation and New Technology*, 11(3), 249-270.

Fu, X. (2012) How does openness affect the importance of incentives for innovation? *Research Policy*, 41, 512-523.

Gaimon, C. & Bailey, J. (2013) Knowledge Management for the Entrepreneurial Venture. *Production and Operations Management*, 22(6), 1429-1438.

Gamatese, J.A. & Hallowell, M. (2011) Enabling and measuring innovation in the construction industry. *Construction Management and Economics*, 29, 553–567.

Gebauer, H., Worch, H. & Truffer, B. (2012) Absorptive capacity, learning processes and combinative capabilities as determinants of strategic innovation. *European Management Journal*, 30, 57– 73.

Gibbert, M., Leibold, M. & Probst, G. (2002) Five Styles of Customer Knowledge Management, and How Smart Companies Use Them To Create Value. *European Management Journal*, 20(5), 459-469.

Gieskes, J. & Van der Heijden, B. (2004) Measuring and Enabling Learning Behaviour in Product Innovation Processes. *Learning Behaviour In Product Innovation*, 13(2), 109-125.

Gil, F., Rico, R., Alcover, C.M. & Barrasa, Á. (2005) Change-oriented leadership, satisfaction and performance in work groups: Effects of team climate and group potency. *Journal of Managerial Psychology*, 20(3/4), 312-328.

Gilley, A., Dixon, P. & Gilley, J.W. (2007) Characteristics of Leadership Effectiveness: Implementing Change and Driving Innovation in Organizations. *Human Resource Development Quarterly*, 19(2), 153-169.

Gumusluoglu, L. & Ilsev, A. (2009) Transformational leadership, creativity, and organizational innovation. *Journal of Business Research*, 62, 461–473.

Guzzo, R.A. & Dickson, M.W. (1996) Team in Organizations: Recent Research on Performance and Effectiveness. *Annual Review of Psychology*, 47, 307-338.

Hackman, J. R. (1990) *Groups that work (and those that don't)*. San Francisco: Jossey-Bass.

Hallgren, E.W. (2009) How to Use an Innovation Audit as a Learning Tool: A Case Study of Enhancing High-Involvement Innovation. *Creativity and Innovation Management*, 18(1), 48-58.

Haner, U-E. (2005) Spaces for Creativity and Innovation in Two Established Organizations. *Creativity and Innovation Management*, 14(3), 288-298.

Harborne, P. & Johne, A. (2003) Creating a Project Climate for Successful Product Innovation. *European Journal of Innovation Management*, 6(2), 118-132.

Hardakker, G., Ahmed, P.K. & Graham, G. (1998) An integrated response towards the pursuit of fast time to market of NPD in European manufacturing organisations. *European Business Review*, 98(3), 172–177.

Hassainen, A. & Dale, C. (2012) Drivers and barriers of new product development and innovation in event venues: A multiple case study. *Journal of Facilities Management*, 10(1), 75-92.

Haucap, J. & Wey, C. (2004) Unionisation Structures And Innovation Incentives. *The Economic Journal*, 114, 149-165.

Hauschildt, J., Kirchmann, E. (2001) Teamwork for Innovation - The "Troika" of Promotors. *R&D Management*, 31, 41-49.

Hauser, H. (1998) Organizational culture and innovativeness of firms – an integrative view. *International Journal of Technology Management*, 16(1/2/3), 239-256.

Hecker, A. & Ganter, A. (2013) The Influence of Product Market Competition on

Technological and Management Innovation: Firm-Level Evidence from a Large-Scale Survey. *European Management Review*, 10, 17–33.

Heffner, M. & Sharif, N. (2008) Knowledge fusion for technological innovation in organizations. *Journal of Knowledge Management*, 12(2), 79-93.

Hemlin, S. & Olsson, L. (2011) Creativity-stimulating leadership: A critical incident study of leaders' influence on creativity in research groups. *Creativity and Innovation Management*, 20, 49-58.

Hidalgo, A. & Albors, J. (2008) Innovation management techniques and tools: a review from theory and practice. *R&D Management*, (38)2, 113-127.

Hine, D. & Ryan, N. (1999) Small service firms – creating value through innovation. *Managing Service Quality*, 9(6), 411-422.

Hoegl, M. (2005) Smaller teams-better teamwork: How to keep project teams small. *Business Horizons*, 48, 209-214.

Hollen, R.M.A., Van Den Bosch, F.A.J. & Volberda, H.W. (2013) The Role of Management Innovation in Enabling Technological Process Innovation: An Inter-Organizational Perspective. *European Management Review*, 10, 35–50.

Holthausen, R.W., Larcker, D.F. & Sloan, R.G. (1994) Annual bonus schemes and the manipulation of earnings. *Journal of Accounting and Economics* 19, 29 74.

Honarpour, A., Jusoh, A. & Nor, K.Md. (2012) Knowledge Management, Total Quality Management and Innovation: A New Look. *Journal of Technology Management & Innovation*, 7(3), 22-31.

Hung, R.Y-Y, Lien, B.Y-H., Fang, S-C. & McLean, G.N. (2010) Knowledge as a facilitator for enhancing innovation performance through total quality management. *Total Quality Management*, 21(4), 425–438.

Hurmelinna-Luakkanen, P. (2011) Enabling collaborative innovation – knowledge protection for knowledge sharing. *European Journal of Innovation Management*, 14(3), 303-321.

Inderst, R. & Klein, M. (2007) Innovation, endogenous overinvestment, and incentive pay. *The Rand Journal of Economics*, 38(4), 881–904.

Inderst, R. (2009) Innovation management in organizations. *European Economic Review*, 53, 871-887.

Ismail, M. (2005) Creative climate and learning organization factors: their contribution towards innovation. *Leadership & Organization Development Journal*, 26(8), 639-654.

Jenssen, J.I. & Nybakk, E. (2009) Inter-Organizational Innovation Promoters In Small, Knowledge-Intensive Firms. *International Journal of Innovation Management*, 13(3), 441–466.

Jablokow, K.W. & Booth, D.E. (2006) The impact and management of cognitive gap in high performance product development organizations. *Journal of Engineering and Technology Management*, 23, 313-336.

Johannessen, J-A. & Olsen, B. (2011) Projects as communicating systems: Creating a culture of innovation and performance. *International Journal of Information Management*, 31, 30-37.

Johannessen, J-A. (2008) Organisational innovation as part of knowledge management. *International Journal of Information Management*, 28, 403-412.

Johnsson, M. (2009) Sälj skinnet innan björnen är skjuten (in Swedish). Östertälje, Östertälje tryckeri.

Johnsson, M. (2014) *Innovation Teams: Before Innovation Work is Begun*. Paper presented at The 25th ISPIM Innovation Conference in Dublin, Ireland.

Johnstone, C., Pairaudeau, G. & Pettersson, J.A. (2011) Creativity, innovation and lean sigma: a controversial combination? *Drug Discovery Today*, 16(1/2), 50-57.

Judge, W.Q., Fryxell, G.E. & Dooley, R.S. (1997) The New Task Of R&D Management: Creating Goal-directed Communities for Innovation. *California Management Review*, 39(3), 72-85.

Kamhawi, E.M. (2012) Knowledge management fishbone: a standard framework of organizational enablers. *Journal of Knowledge Management*, 16(5), 808-828.

Kask, T. (2011) Strategic decisions as drivers of innovation: the case of MicroLink. *Baltic Journal of Management*, 6(3), 300-319.

Kathleen, K.M. (2012) *Sustainability and Innovation. Creating Change that Engages the Workforce*. JCC, 46, 175-187.

Kay, L. (2011) The effect of inducement prizes on innovation: evidence from the Ansari X Prize and the Northrop Grumman Lunar Lander Challenge. *R&D Management*, 41, 360-377.

Kayabasi, A. & Duran, C., Çentindere (2013) An Analysis of the Relationship Between the Elements Encouraging Innovation and Innovation Performance for SMEs. *European Journal of Business and Economics*, 4.

Kelly, T. (2005) Ten faces of Innovation. USA, Broadway Business.

Kesting, P. & Ulhöj, J.P. (2010) Employee-driven innovation: extending the license to foster innovation. *Management Decision*, 48(1), 65-84.

Kianto, A. (2011) Enabling Innovation in Knowledge Worker Teams. International *Journal of Intellectual Capital*, 8(1), 30-49.

Kindström, D. & Kowalkowski, C., Sandberg, E. (2012) Enabling service innovation: A dynamic capabilities approach. *Journal of Business Research*, 66, 1063-1073.

Koberg, C.S., Uhlenbruck, N. & Sarason, Y. (1996) Facilitators Of Organizational Innovation: The Role Of Life-Cycle Stage. *Journal of Business Venturing*, 11, 133-149.

Kodama, M. (2000) Creating New Services Based on the Formation of a Strategic Community with Customers: A Case Study of Innovation Involving IT and Multimedia Technology in the Field of Veterinary Medicine. *Networking Veterinary Medicine Services*, 9(3), 171-184.

Kollmann, T. & Stöckmann, C. (2010) Antecedents of strategic ambidexterity: effects of entrepreneurial orientation on exploratory and exploitative innovations in adolescent organisations. *International Journal of Technology Management*, 52(1/2), 153-174.

Kramer, J-P., Marinelli, E., Iammarino, S. & Diez, J.R. (2011) Intangible assets as drivers of innovation: Empirical evidence on multinational enterprises in

German and UK regional systems of innovation. *Technovation*, 31, 447-458.

Kristiansen, M. & Bloch-Poulsen, J. (2010) Employee Driven Innovation in Team. (EDIT) – Innovative Potential, Dialogue, and Dissensus. International Journal of Action Research, 6(2-3), 155-195.

Kuckertz, A. & Kohtamäki, M., Droge gen. Körber, C. (2010) The fast eat the slow – the impact of strategy and innovation timing on the success of technology-oriented ventures. *International Journal of Technology Management*, 52(1/2), 175–188.

Lans, H. (1997) Uppfinn framtiden (in Swedish). Nynäshamn, Malms Repro.

Laursen, K. (2011) User–producer interaction as a driver of innovation: costs and advantages in an open innovation model. *Science and Public Policy*, 38(9), 713–723

Leavy, B. (2005) A leader's guide to creating an innovation culture. *Strategy & Leadership*, 4, 38-45.

Lei, D. (2003) Competition, cooperation and learning: the new dynamics of strategy and organization design for the innovation net. *International Journal of Technology Management*, 26(7), 694-716.

Lemon, M., & Sahota, P. S. (2004) Organizational culture as a knowledge repository for increased innovative capacity. *Technovation*, 24(6), 483-498.

Lerner, J. & Wulf, J. (2007) Innovation And Incentives: Evidence From Corporate R&D. *The Review of Economics and Statistics*, 89(4): 634-644

Lettice, F. & Thomond, P. (2008) Allocating resources to disruptive innovation projects: challenging mental models and overcoming management resistance. *International Journal of Technology Management*, 44(1/2), 140-159.

Liao,S-H. & Wu, C-C. (2010) System perspective of knowledge management, organizational learning, and organizational innovation. *Expert Systems with Applications*, 37, 1096-1103.

Loan, P. (2006) Review of The New Knowledge Management: Complexity, Learning and Sustainable Innovation. *On the Horizon*, 14(3) 130-138.

Logman, M. (2007) Logical brand management in a dynamic context of growth and innovation. *Journal of Product & Brand Management*, 16(4), 257-268.

Longo, F. (2007) Implementing managerial innovations in primary care: Can we rank change drivers in complex adaptive organizations? *Health Care Management Review*, 213-225.

López-Fernández, M. C., Serrano-Bedina, A. M. & Gómez-López, R. (2011) Factors Encouraging Innovation in Spanish Hospitality Firms. *Cornell Hospitality Quarterly*, 52(2) 144-152.

Liu, M-S. (2013) Impact of knowledge incentive mechanisms on individual knowledge creation behavior—An empirical study for Taiwanese R&D professionals. *International Journal of Information Management*, 32, 442-450.

Lukes, M. (2012) Supporting Entrepreneurial Behaviour and Innovation in Organizations. *Central European Business Review Research Papers*, 2, 29-36.

Lumpkin, G.T. & Dess, G. (2001) Linking Two Dimensions Of Entrepreneurial

Orientation To Firm Performance: The Moderating Role Of Environment And Industry Life Cycle. *Journal of Business Venturing*, 16, 429–451.

Majumdar, S.K. (1999) Sluggish Giants, Sticky Cultures, And Dynamic Capability Transformation. *Journal of Business Venturing*, 15, 59–78.

Manley, K., McFallan, S. (2006) Exploring the drivers of firm-level innovation in the construction industry. *Construction Management and Economics*, 24, 911–920.

Mansfeld, M.N., Hölzle, K. & Gemünden, H.G. (2010) Personal Characteristics Of Innovators - An Empirical Study Of Roles In Innovation Managment. *International Journal of Innovation Management*, 14(6), 1129-1147.

Mansikkamäki, P., Mäntysalo, M. & Rönkkä, R. (2007) Integrative Technologies Complicate Communication during Development Work Context: Industry-Academy Collaboration. Systemics, *Cybernetics And Informatics*, 5(3), 9-15.

Manso, G. (2011) Motivating Innovation. *The Journal of Finance*, 66(5), 1823-1860.

Masoulas, V. (1998) Organizational requirements definition for intellectual capital management. *International Journal of Technology Management*, 16(1/2), 126-144.

Maqsood, T. & Finegan, A. (2009) A knowledge management approach to innovation and learning in the construction industry. *International Journal of Managing Projects in Business*, 2, 297-307.

Marion, R. & Uhl-bien, M. (2002) Leadership in complex organizations. *The Leadership Quarterly*, 12, 389–418.

Martinsuo, M., Hensman, N., Artto, K., Kujala, J. & Jaafari, A. (2006) Project-Based Management as an Organizational Innovation: Drivers, Changes, and Benefits of Adopting Project based Management. *Project Management Journal*, 87-97.

Matjazˇ, M., Kajzer, S., Potocan, V., Rosi, B. & Knez-Riedl, J. (2006) Interdependence of systems theories – potential innovation supporting innovation. *Kybernetes*, 35, 942-954.

McAdam, R. (2000) Knowledge Management as a Catalyst for Innovation within Organizations: A Qualitative Study. *Knowledge and Process Management*, 7(4), 233-241.

McGurk, J. & Baron, A. (2012) Knowledge management – time to focus on purpose and motivation. Strategic HR Review, 11(6), 316-321.

Mele, C., Spena, T.R. & Colurcio, M. (2012) Co-creating value innovation through resource integration. *International Journal of Quality and Service Sciences*, 2(1), 60-78.

Mentzas, G. (2004) A Strategic Management Framework for Leveraging Knowledge Assests. *International Journal of Innovation and Learning*, 1-30.

Michanek, J. & Breiler, A. (2004) *Idéagenten - en handbok i idea management* (in Swedish), Jönköping, Sweden, Brain Books AB.

Mol, M.J. & Birkinshaw, J. (2009) The sources of management innovation: When firms introduce new management practices. *Journal of Business Research*, 62, 1269-1280.

Mooi, E.A. & Frambach, R.T. (2012) Encouraging innovation in business

relationships—A research note. *Journal of Business Research*, 65, 1025-1030.

Morgan, C.W., Blake, A. & Poyago-Theotoky, J.A. (2004) The management of technological innovation: lessons from case studies in the UK food and drink industry. *International Journal of Biotechnology*, 5(3/4), 334-353.

Morris, M.H., Allen, J., Schindehutte, M. & Avila, R. (2006) Balanced Management Control Systems as a Mechanism for Achieving Corporate Entrepreneurship. *Journal of Managerial Issues*, 18(4), 468-493.

Nanda, T. & Singh, T.P. (2009) Determinants of creativity and innovation in the workplace: a comprehensive review. International Journal of Technology, *Policy and Management*, 9(1), 84-106.

Narasimhalu, A.D. (2005) *Innovation Cube: Triggers, Drivers and Enablers for Successful Innovations. In: International Society of Professional Innovation Management*, Porto, Portugal 19th-22nd of June.

Newton, K. (1998) The high performance workplace: HR-based management innovations in Canada. *International Journal of Technology Management*, 16(1/2/3), 177-192.

Nicolaou, N., Shane, S., Cherkas, L. & Spector, T.D. (2009) Organizational Behavior and Human Decision Processes. *Organizational Behavior and Human Decision Processes*, 110, 108-117.

Noke, H., Perrons, R.K. & Hughes, M. (2008) Strategic dalliances as an enabler for discontinuous innovation in slow clockspeed industries: evidence from the oil and gas industry. *R&D Management*, 38, 2, 129-139.

Nonaka, I. & Takeuchi, H. (1995) *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

Nybakk, E., Crespell, P. & Hansen, E. (2011) Climate for Innovation and Innovation Strategy as Drivers for Success in the Wood Industry: Moderation Effects of Firm Size, Industry Sector, and Country of Operation. *Silva Fennica* 45(3), 415-430.

O'Brian, C. & Smith, S.J.E. (1995) Strategies for encouraging and managing technological innovation. *International Journal of Production Economics*, 41, 303-310.

O´Connor, G.C. & DeMartino, R. (1997) Organizing for Radical Innovation: An Exploratory Study of the Structural Aspects of RI Management Systems in Large Established Firms. *Journal of Product Innovation Management*; 23,475-497.

OECD (2005) *Oslo Manual – Guidelines for Collecting and Interpreting Innovation Data*.

Olsen, J.E. & Haslett, T. (2002) Strategic Management in Action. *Systemic Practice and Action Research*, 15(6), 449-464.

Orcutt, L.H. & AlKadri, M.Y. (2009) *Barriers and Enablers of Innovation: A Pilot Survey of Transportation Professionals*. Transportation Research Record.

Ottosson, S. (2012) Dynamisk Produktutveckling (in Swedish). Floda, Tervix AB.

Overvest, M. & Veldman, J. (2008) Managerial Incentives for Process Innovation, Managerial and Decision. *Economics*, 29, 539-545.

Paasi, J., Valkokari, K., Rantala, T., Hytönen, H., Nystén-Haarala, S. & Huhtilainen, L. (2010) Innovation Management Challenges Of A System Integrator In Innovation Networks. *International Journal of Innovation Management*, 14(6), 1047-1064.

Palacios, P., Gil, I. & Garragos, F. (2009) The impact of knowledge management on innovation and entrepreneurship in the biotechnology and telecommunications industries. *Small Business Economy*, 32, 291-301.

Paladino, A. (2007) Investigating the Drivers of Innovation and New Product Success: A Comparison of Strategic Orientations. *Journal of Product Innovation Management*, 24, 534-553.

Panayides, P. (2006) Enhancing innovation capability through relationship management and implications for performance. *European Journal of Innovation Management*, 9(4), 466-483.

Panesar, S.S. & Markeset, T. (2008) Development of a framework for industrial service innovation management and coordination. *Journal of Quality in Maintenance Engineering*, 14(2), 177-193.

Park, J.S. (2005) Opportunity recognition and product innovation in entrepreneurial hi-tech start-ups: a new perspective and supporting case study. *Technovation*, 25, 739-752.

Parolin, S.R.H, Vasconcellos, E., Volpato, M. & Laurindo, A.M. (2013) Barriers and Facilitators of Collaborative Management in Technological Innovation Projects. *Journal of Technology Management & Innovation*, 8, 151-164.

Pattersson, M.L. (2009). Innovation as a system. *Research-technology Management*, September-October: 42-51.

Peschl, M.F. & Fundneider, T. (2012) Spaces Enabling Game-Changing and Sustaining Innovations: Why Space Matters For Knowledge Creation and Innovation. Journal of Organisational *Transformation and Social Change*, 9(1), 41-61.

Petty, E.R. (1983) Engineering Curricula for Encouraging Creativity and Innovation. *European Journal of Engineering Education*, 8, 29-43.

Richtnér, A. & Åhlström, P. (2010) Top Management Control and Knowledge Creation in New Product Development International. *Journal of Operations & Production Management*, 30(10), 1006-1031.

Rigtering, J.P.C. & Weitzel, U. (2013) Work Context and Employee Behaviour as Antecedents for Intrapreneurship. *International Entrepreneurship and Management Journal*, 9, 337-360.

Ritala, P. & Hurmelinna-Laukkanen, P. (2009) What's In It For Me? Creating And Appropriating Value In Innovation-Related Coopetition. *Technovation*, 29, 819-828.

Rogers, E.W. (1998) Enabling Innovative Thinking: Fostering the Art of Knowledge Crafting. *International Journal of Technology Management*, 16(1/2/3), 11-23.

Romero, D. & Molina, A. (2011) Collaborative Networked Organisations and Customer Communities: Value Co-Creation and Co-Innovation in the Networking Era. *Production Planning & Control*, 22(5–6), 447-472.

Rosing, K., Frese, M. & Bausch, A. (2011) Explaining the Heterogeneity Of The Leadership-Innovation Relationship: Ambidextrous Leadership. *The Leadership Quarterly*, 22, 956-974.

Ross, T., Mitchell, V.A. & May, A.J. (2012) Bottom-Up Grassroots Innovation in Transport: Motivations, Barriers and Enablers. *Transportation Planning and Technology*, 35(4), 469-489.

Salge, T.O., Bohné, T.M., Farchi, T. & Piening, E.P. (2012) Harnessing The Value Of Open Innovation: The Moderating Role Of Innovation Management. *International Journal of Innovation Management*, 16(3).

Sampson, R.C. (2007) R&D Alliances and Firm Performance: The Impact of Technological Diversity and Alliance Organization on Innovation. *Academy of Management Journal*, 50(29, 364-386.

Sarros, J. C., Cooper, B. K., & Santora, J.C. (2008). Building a climate for innovation through transformational leadership and organizational culture. *Journal of Leadership & Organizational Studies*, 15(2), 145-158.

Schon, D.A. (1991) *The Reflective Practitioner – How Professionals Think in Action*. Ashgate Publishing Limited, UK.

Searle, R.H. & Ball, K.S. (2003) Supporting Innovation through HR Policy: Evidence from the UK. *Creativity and Innovation Management*, 12(1), 50-62.

Shang, S.S.C., Lin, S-F. & Wu, Y-L. (2009) Service innovation through dynamic knowledge management. *Industrial Management & Data Systems*, 109(3), 322-337.

Sheikh, S. (2012) Do CEO compensation incentives affect firm innovation? *Review of Accounting and Finance*, 11(1), 4-39.

Shipton, H., West, M. A., Dawson,J., Birdi, K., & Patterson, M. (2006). HRM as a predictor of innovation. *Human Resource Management Journal*, 16(1), 3-27.

Smart, P., Bessant, J. & Gupta, A. (2007). Towards Technological Rules for Designing Innovation Networks: A Dynamic Capabilities View. *International Journal of Operations & Production Management*, 27(10), 1069-1092.

Smith, M., Busi, M., Ball, P. & Van Der Meer, R. (2008) Factors Influencing An Organisation's Ability To Manage Innovation: A Structured Literature Review And Conceptual Model. *International Journal of Innovation Management*, 12(4), 655-676.

Smith, S., Smith, G. & Shen, Y-T. (2012) Redesign for Product Innovation. *Design Studies*, 33(2), 160-184.

Steele, J. & Murray, M. (2004) Creating, supporting and sustaining a culture of innovation. Engineering, *Construction and Architectural Management*, 11(5), 316-322.

Stempfle, J. (2011) Overcoming Organizational Fixation: Creating and Sustaining an Innovation Culture. *Journal of Creative Behavior*, 45(2), 116-129.

Tahirsylaj, A.S. (2012) Stimulating creativity and innovation through Intelligent Fast Failure. *Thinking Skills and Creativity*, 7, 265-270.

Tan, R. (2013) Seven Stimuli to Identify Opportunities of Innovation: A Practice of Training Innovative Engineers and Some Findings in China. *American Journal of Industrial and Business Management*, 3, 725-739.

Taylor, A. & Helfat, C.E. (2009) Organizational Linkages for Surviving Technological Change: Complementary Assets, Middle Management, and Ambidexterity. *Organization Science*, 20(4), 718-739.

Tidd, J. & Bessant, J. (2013) *Managing Innovation - Integrating Technological, Market and Organizational Change*, fifth edition. West Sussex, John Wiley & Sons Ltd.

Timmermans, O., Van Linge, R., Van Petegem, P., Van Rompaey, B. & Denekens, J. (2011) Team learning and innovation in nursing, a review of the literature. *Nurse Education Today*, 32, 65-70.

Tranfield; D., Young, M., Parington, D., Bessant, J. & Sapsed, J. (2003) Knowledge Management Routines For Innovation Projects: Developing A Hierarchical Process Model. *International Journal of Innovation Management*, 7(1), 27-49.

Trott. P. (2012) *Innovation Management and New Product Development*, Fifth edition. Essex, Pearson Education Ltd.

Tuckmann, B.W. & Jensen, M.A.C. (1977) Stages of Small-Group Development Revisited. *Group and Organization Management*, 2, 419-427.

Tushman, M., & Nadler, D. (1986). Organizing for innovation. *California Management Review*, 28(3), 74-92.

Vaghely, I.P. & Julien, P-A. (2008) Are opportunities recognized or constructed? An information perspective on entrepreneurial opportunity identification. *Journal of Business Venturing*, 25, 73-86.

Vale, P.A. & Addison, M. (2002) Promoting Entrepreneurship and Innovation in a Large Company: Creating a Virtual Portfolio. *Journal of Change Management*, 2(4), 334-343.

Vashishtha, V.K., Makade, R. & Mehla, N. (2011) Advancement of Rapid Prototyping in Aerospace Industry - A Review. International Journal of *Engineering Science and Technology*, 3(3), 2486-2493.

VINNOVA (2012) Innovationsledning och kreativitet i svenska företag (in Swedish). Edited by Richtner, A., Frishammar, J. Sweden, Edita.

Watkins, K.E. & Marsick, V. (1996), Dimensions of the Learning Organization Questionnaire. *Partners of the Learning Organization*, Warwick, RI.

Weisenfeld, U. (2003) Engagement in Innovation Management: Perceptions and Interests in the GM Debate. *Engagement in Innovation Management*, 12(4), 211-220.

Weiss, M., Hoegl, M., Gibbert, M. (2011) Making Virtue of Necessity: The Role of Team Climate for Innovation in Resource-Constrained Innovation Projects. *Journal of Product Innovation Management*, 28(S1), 196-207.

West, M., Hirst, G., Richter, A. & Shipton, H. (2004) Twelve steps to heaven:

Successfully managing change through developing innovative teams. *European Journal of Work and Organizational Psychology*, 13(2), 269–299.

Wheelan, S. A. (2013) *Creating Effective Teams – A Guide for Members and Leaders*. Lund, Studentlitteratur AB

Yang, Y. & Konrad, A.M. (2011) Diversity and organizational innovation: The role of employee involvement Journal of Organizational Behavior, *Journal of Organizational Behaviour*, 32, 1062-1083.

Yesil, S., Büyükbese, T. & Koska, A. (2013) Exploring The Link Between Knowledge Sharing Enablers, Innovation Capability And Innovation Performance. *International Journal of Innovation Management*, 17(4).

Yu, D., Hang, C.C. (2010) A Reflective Review of Disruptive Innovation Theory. *International Journal of Management Reviews*, 12, 435-452.

Zuidema, K.R., Kleiner, B.H. (1994) Self-directed work groups gain popularity. *Business Credit*, 96(9), 21-26.

Journal of Innovation Management
JIM 5, 3 (2017) 122-139
HANDLE: http://hdl.handle.net/10216/107952
SM: Jan/2017 AM: Oct/2017

Short-Message Service as a Digital Disruptor of Industry

Jarno Lähteenmäki[1], Heikki Hämmäinen[1], Kalevi Kilkki[1], Petteri Alahuhta[2]

[1] Department of Communications and Networking, Aalto University, Espoo, Finland
{jarno.lahteenmaki, heikki.hammainen, kalevi.kilkki}@aalto.fi

[2] VTT Technical Research Centre of Finland Ltd, Oulu, Finland
petteri.alahuhta@vtt.fi

Abstract. Short-message service (SMS) has disrupted several communications ecosystem stakeholders. With this new technology, consumers have adopted new ways to communicate with each other and companies have radically improved their existing processes and ways to deliver their services. Furthermore, SMS has enabled the emergence of machine-to-machine type services. The Disruption Framework is a theoretical model that can be used for identifying the process of technology diffusion from a scientific level to a level of social norms. SMS is found to fit within the model of Disruption Framework. The study reveals that the service has progressed to all levels in the model thus the service has been diffused at an almost maximal manner through the ecosystem. Shifts from one level and an industry to another level can be pinpointed and diffusion into different ecosystem layers can be identified. SMS reached its maturity phase in the early 2000s. However, there are clear indications that novel technologies are starting to disrupt SMS ecosystem stakeholders since early adopters of those new technologies are abandoning SMS.

Keywords. Short-message service, Disruption Framework.

1 Introduction

Short-Message Service (SMS) is a messaging technology that utilizes the signalling channel of a mobile network to carry user messages. The technology was standardized in the late 1980s together with Global System for Mobile Communication (GSM) standards by the European Conference of Postal and Telecommunications Administrations (CEPT) and the European Telecommunications Standards Institute (ETSI).

Usage volumes of SMS indicate that the technology has had an influence on consumer and business markets (Ficora, 2016). However, there continues to be uncertainty about the extent SMS has been disruptive. This paper studies the history of SMS using the Disruption Framework -model to gain a better understanding about which layers of the ecosystem SMS have actually been disrupted.

The objective of this study is to gain a better understanding about how SMS has diffused into the ecosystems. Furthermore, we attempt to pinpoint which of the ecosystem stakeholders have been disrupted the most due to SMS technology. To achieve the previously mentioned targets we use the Disruption Framework established by Kilkki et al. (2017). Thus, this study functions as a real world sample

ISSN 2183-0606
http://www.open-jim.org

for the Disruption Framework theory. The study does not attempt to take a holistic approach but builds indications from the bottom up that SMS as a technology actually followed the theory of the Disruption Framework. To articulate that in the form of a research question:

> *How has SMS diffused into the ecosystem and are there any ecosystem stakeholders that have seen SMS as a disruptive innovation?*

The remainder of this paper is organized as follows. Section 2 briefly summarizes research methods, related work and how the data is collected. Section 3 describes the Disruption Framework that is used as an assessment tool in the study. Section 4 summarizes the timeline of the history of SMS. Section 5 walks through the disruption process and places events caused by SMS into the model. Section 6 summarizes the most important results of the study. Section 7 discusses implications of the results and Section 8 concludes the study by summarizing the key findings and contributions.

2 Previous Work and Research Methods

Historical data related to SMS was collected using literature review and gathering statistics from publicly available sources. Furthermore, historical industry conditions were discussed in semi-structured interviews with industry specialists.

This study mainly relies on Makkonen (2015) and Trosby et al. (2010). The statistics are collected from Google (2016), IEEE (2016), Edita (2016) and Ficora (2016-a).

2.1 Previous Work

There are several authors, such as Makkonen (2015) and Trosby et al. (2010), who have written about the history of SMS. All of these publications together depict quite an accurate portrayal of how SMS was born and how it was developed. Certainly, there are some inaccuracies in the history, mainly due to a lack of contemporary researches during past times but those imprecisions are not found to be critical.

Hong et al. (2008) presents results of consumer behaviour with regard to mobile services. Many consumers use SMS service for building social connections and specifically younger generations tend to build and strengthen group relations using mobile messaging services. This study combines this observation with the diffusion model.

2.2 Research Methods

Mobile services and specifically SMS, is a studied field. As Figure 3-a point out, there are hundreds of different scientific papers published regarding the subject. This study builds on those previous results.

The actual disruption modelling is carried out by using the Disruption Framework (Kilkki et al., 2017). This theory is described more thoroughly in Section 3.

2.3 Expert interviews

During the research industry experts were interviewed to gain a deeper insight into the industry conditions that were present when SMS technologies and applications were developed. All interviews had a duration of approximately two hours.

All interviewed persons worked in SMS service development positions, and all of them were employed in these positions when SMS services began to emerge. These individuals represent different layers in the disruption model.

Interviews were carried out using the semi-structured model. The interview transcripts were codified and recognized events were chronically placed into a list. These events are depicted in Figure 5-a and 5-b.

Table 1 contains a list of experts that were interviewed for the study. Names of the interviewed persons, interviewer and interview date are located in the References section.

Table 1. Background information of the interviewed persons

Job title	Years of industry experience	Location of interview	The layer in the disruption model
Communications network specialist	28	Helsinki, Finland	Industry / Regulator
Head of Ecosystems Research	35	Espoo, Finland	Science / R&D / Firm
Head of Business Line	27	Helsinki, Finland	Science / R&D / Firm

3 Disruption Framework

The theory of disruptive innovation was presented by Christensen (1997). Since then, the term disruption has been taken into use in various contexts - sometimes too loosely. There have been several efforts to clarify what disruptions actually are and how they emerge (Markides, 2006; Schmidt et al., 2008; Ritala et al. 2016).

A process and agent-based view could be taken to gain better understanding of a disruption. Kilkki et al. (2017) presents the Disruption Framework which brings structure to the disruption process. The core essence of the framework is the idea that a disruption is an event seen by the agent in an ecosystem. This agent-based view conveniently omits entire ecosystem wide change momentum. Instead, it allows for usage of the term disruption in a small and easily manageable context. The framework also defines relationships between different innovation sources. Kilkki et al. (2017) defines a disruption as,

> *An agent is disrupted when the agent has to redesign its strategy in order to survive a change in the environment. From the perspective of a system, disruption is an event in which a substantial share of agents belonging to the system are disrupted.*

The disruption framework model, as seen in Figure 1, divides the disruption process into seven layers of stakeholders. Each layer has a causal relationship with neighbouring layers. For instance, theories have previously emerged from fields of science. Gradually, those theories develop and, using this novel knowledge, new technologies are invented in corporations' and universities' research and development (R&D) units. Those technologies are tools for firm level internal processes that eventually may realize in an assortment of applications in the industry. Due to these new revolutionary products, the behaviour of consumers can change. These behavioural changes may realize as complaints to the market regulator, which sets rules to fix causes behind complaints. Furthermore, a disruptive technology may eventually have an impact on social order. The causal process can go both ways in the model. For instance, consumer behavioural changes may change industry architectures and push for change further in the process.

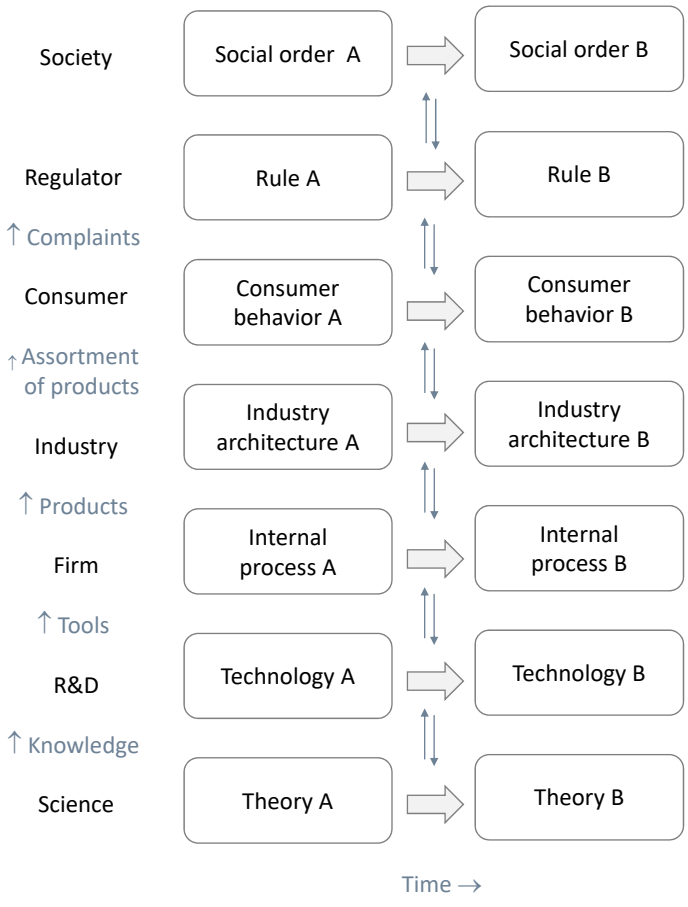


Fig. 1. The Disruption Framework (after Kilkki et al., 2017)

As referred to earlier, the disruption is defined as "…an agent is disrupted when the agent has to redesign its strategy in order to survive…". The disruption framework

also proposes a formal way to model those strategies made by an agent. As seen in Figure 2, there are several courses of actions that can be taken. In case A, an agent can expand its operations to an alternative industry thereby leveraging innovation made on the other industry. It is also common that incumbents of the target industry (agent C) try to offer more advanced and costly products to maintain industry position. In case B, an agent can enter an alternative industry with a low-end feature set offering a more cost efficient way than competitors, causing others to flee the market (the agent D). It is also possible that a new agent enters the market with an innovation (the agent E).

Since the Disruption Framework model is quite easy to apply, it is natural to assume the concept is easy to master. From a technical standpoint, the model is simple, however, it is conceptually strong. It combines parts from social sciences using Agent-based modelling (ABM) (Bonabeau, 2002) to understand how individual agents respond to signals. It utilizes diffusion theory (Rogers, 2003) to understand dynamics between agents. It separates product innovations and new to the market innovations from technological innovations as did Markides (2006).

Before we discuss more about the results of how the disruption framework is applied, let us briefly summarize the history of our chosen case study topic, the SMS.

4 A Brief History of SMS

The telecommunications industry has grown from being a non-existent entity to becoming a vital element of global businesses in just 200 years. During the early 20th century, technologies matured and commoditized so that communication solutions were achievable by consumers in the Western world. However, before digitalization and global standards, wide scale mobile communication was not feasible for most consumers due to price constraints.

In the 1970s and 1980s, the communications industry was primarily based on national monopoly operators which typically also had a regulatory authority role. Furthermore, in some countries, there were state owned network equipment manufacturers, such as Televa in Finland (Huusko, 2009) and Ellemtel in Sweden (Telia, 2017, pp.7). In European countries, communications specifications and standardization was driven by national governments in CEPT (Trosby, 2010).

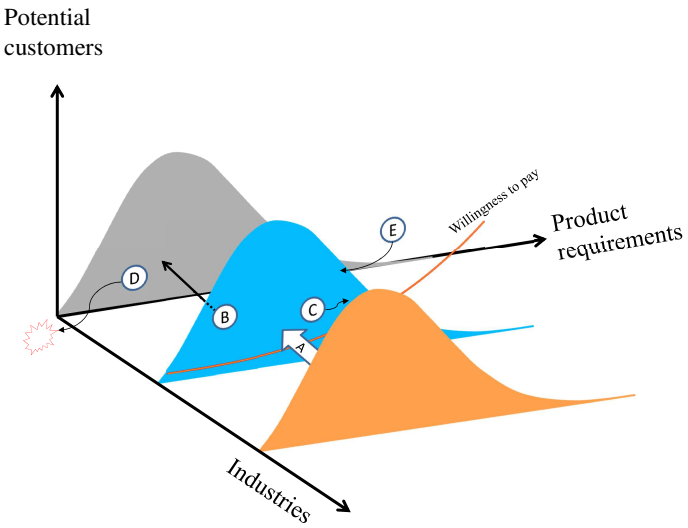


Fig 2. Model of disruption transition between industries (after Kilkki et al., 2017)

In the mid-1980s, the communications market began the process of transforming into a more open and international mode. In Europe, the governments of France, the United Kingdom, Italy and West Germany agreed to co-operate in the arena of communications development (Makkonen, 2015). CEPT made a decision to plan for European wide mobile communication standards (Trosby, 2010). At this time, government driven development also began to decline.

The service that we nowadays refer to as an SMS was not the first mobile messaging technology. Previously, Data and Messaging Service (DMS) technology allowed for the transfer of messages using a signalling channel in Nordic Mobile Telephone (NMT) service networks. However, deployments were rare. Polish, Russia and Bulgarian NMT networks offered the service. However, a limiting factor of the adoption was the lack of a handset feature to send actual messages. Consequently, a separate device was required to use the service. This existing knowledge and competencies were leveraged when GSM standardization was instituted.

The standardization role of CEPT was transferred to ETSI in 1987. While CEPT only accepted governments as members, ETSI was open also for network equipment manufacturers and operators. ETSI's GSM standardization initially focused on voice communications. The SMS specification was also released in phase 1 but it was defined as an auxiliary value added feature, i.e. it was perceived as unimportant. (Ali-Vehmas, 2016)

Balston (1989a) expresses the industry conditions and environment quite well in his discussion regarding the future of the GSM. "The GSM Commitee (sic) has adopted a pragmatic attitude towards its task. It is clearly a partnership between operators and industry which is succeeding, or perhaps indeed because of, deregulation and the competitive pressures being introduced both in the PTTs and their industrial base."

Similar to NMT, the first GSM handsets did not contain the features necessary to send

SMSs. In roughly 1994, some handset manufacturers finally began to include two-way SMS features in their phones. The SMS concept was introduced to consumers as a handset feature rather than as a network service. Since then, SMS technologies have spread into a vast number of different applications. Today, it is not just individuals who use it for everyday communications. In fact, SMS technology has enabled totally new ecosystems and industries to emerge.

Historically, there are two distinctive paths in the evolution of SMS services. First, people oriented applications are designed to be interactive between humans and are used by a handset. Second, industrial oriented applications are the basis for M2M type use cases. In the following sections, we discuss how SMS fits into the general Disruption Framework model.

5 Disruption Framework Fit

As discussed in Section 3, the Disruption framework outlines a process that might lead to an event where an agent gets disrupted. In this section, we walk through the process and place events caused by SMS into the model.

5.1 Theories and Technologies

Short messaging, as a concept, was discovered in the late 1980s by scholars. For instance, Balston (1989b) discusses the impacts of customer mobility and observes that SMS can be used for sending messages to a user handset. There are several papers after that published on the subject. For example, searches of Google Scholar and IEEE xplore uncovered a total of 155 papers mentioning SMS that were published between the years 1989 and 1997.

Several different stakeholders became interested in SMS during its first decade. From those 155 papers, universities published 38%, network service providers 16%, network equipment manufacturers 15%, other corporations 15%, different research institutes 9% and consulting companies 7%. The driving force behind SMS technology was standardisation administrations, such as national regulators and operators. Those entities were also the stakeholders that published the earliest papers. Hence, this indicates that the disruption process might have started from the industry architectural level and then progressed downwards to the organizational, technological and theorical levels.

The yearly peak publication rate was achieved in 2010 which is relative late. There are a couple explanations for this delay. In early years, scholars' interest was more on the theoretical, core technological side and only on the telecommunications industry. Later, the focus shifted to numerous applications of SMS technology and interest diverged into several different industries. The time-series for the published papers can be seen in Figure 3-a.

5.2 Firm level internal processes

GSM technology was initially specified in Europe for European operators in the late 1980s. At that time, elsewhere in the world, operators were using proprietary mobile messaging solutions, thus, a customer of one operator could not communicate with a customer of another operator. GSM standardization resolved this limitation. Hence, the GSM based SMS service was benefited due to network externalities, i.e., standardization of the GSM and SMS technologies brought more value to a customer and adoption of GSM technology also accelerated also adoption of SMS services.

Although technologies are typically patented by their inventors, SMS based patents are seen as unimportant to the speed of SMS deployments. However, in the Google Patents archive, at the time of this study there are more than a hundred thousand patents that are somehow related to Short Message Service. Patents represent a firm level internal process to protect inventions before those creations are presented to the industry. While these patented features might generate some revenue for a network equipment manufacturer in the form of license royalties, those patents are also creating a barrier for new entrants into the market. Furthermore, there have been several patent related court cases during the last 20 years between handset manufacturers.

The earliest SMS related patent was filed in the 90s. It was during the same timeframe that GSM standards were finalized and a few years after the first SMS related scientific paper was published. The amount of filed patents grew at an accelerated speed until 2007, when the amount of filed patents stabilized to a yearly rate of 10,000. There are some indications that patents per year have started to decline, i.e. firms are generating less protectable innovations than they were earlier. A time-series of filed patents per year can be seen in Figure 3-b.

During the early years of SMS services, network providers had several different scenarios for SMS products and charging models. Initially, some providers considered SMS to be a value added service that would be a separately chargeable service. Furthermore, network service providers' roaming charging and billing capabilities were limited, thus, some users were able to send and receive messages without paying. However, by the end of the 90s, the SMS service model reached a dominant design phase and a pay-per-use model was established in most countries. Nevertheless, there are some exceptions, such as Indonesian' operators, who use flat-fee pricing.

5.3 Industry

Standardization can be seen as an industry level method to introduce new interoperable services to the industry. When standards are defined, the era of fermentation ends, and dominant design for services are established. However, it can be assumed that most standards leave room for implementation level innovations.

The first application for sending SMS messages was delivery of operator service configuration messages to users' handsets. This was introduced in the mid-90s. Later in the 90s several service companies from number of different industries observed that SMS can also be used for carrying user requests to a non-mobile system that provides value-added services (VAS). These services created totally new business

models and enabled companies to offer digital channels for their services. For instance, mobile payment (bus and tram tickets) and mobile banking (small loan requests) are just a few of those business models. Many of these use cases can be seen as low-end disruptions for service companies. Hence, new business models were introduced into existing markets. Nevertheless, from a network service provider's point of view, the same kind of revenue sharing model was deployed that was in voice based service numbers, i.e. from a network service provider's point of view there was no disruption.

Some service companies discovered that they could use SMS to send different types of information and queries to users. For instance, instant customer service surveys (customer satisfaction queries) enabled companies to establish a new pace for development of customer servicing processes; likewise, SMS based one-time-passwords could be used in application authentication processes to reduce the risk of cyber-crime. Machine-to-human communication also enabled new forms of industries to emerge. There are a few new-to-the-world products that were introduced, but mostly these can be seen as a low-end disruption.

In the late 90s, the Finnish regulatory authority introduced SMS service numbers for companies in Finland. These numbers are used in person-to-machine (P2M) and machine-to-person (M2P) services to indicate the type of service. Time-series for those assigned SMS service numbers in Finland can be seen in Figure 3-c. The amount of numbers assigned yearly has remained quite stable over the past 16 years. Growth remains strong and there are no clear signs of a market decline. This same service number model has been applied in some other countries, as well. All previously mentioned use cases are well known by consumer users. However, one could argue that the most revolutionary use of SMS is actually machine-to-machine communication (M2M).

Currently, there are hundreds of different SMS based applications available in the M2M domain. For instance, electric companies have installed mobile connected smart meter devices that enable remote consumption monitoring using SMS technology, thus, they have removed the need for manual reporting and redundant labour. In the oil industry, gas companies monitor tank levels to optimize refills. SMS technology has enabled utility companies to digitalize their firm level internal processes to reduce manual work. The driving force is the desire to improve operational efficiency in those companies that have selected cost-leadership as their primary strategy, as most utility companies have done. In these cases, SMS can be seen as a disruptive innovation. However, it can be argued that companies have not actually changed their entire strategy due to SMS, but rather, have just fine tuned their strategy implementation. Nevertheless, there is a common trend that companies are adapting their digitalization strategies which also covers SMS services.

On the other hand, there are some attempts to replicate the success of SMS. In the mobile market, email was viewed as an alternative technology but operators found the transaction based billing model more attractive, thus, operators advocated Multimedia Messaging Service (MMS) technology instead. However, MMS was unsuccessful in comparison to what was predicted for it and it was unable to disrupt SMS or any other messaging technologies. Consequently, it remained a niche market. There are some indications that the reason for the MMS failure was the service pricing.

5.4 Consumer

From a consumer's view point, at least four different use cases can be recognized that SMS has enabled. The first is person to person communication. In this model, a service user communicates directly with another person using a mobile handset. The person to person communication model has changed consumer behaviour the most so far. All modern handsets contain the SMS feature and it is a significantly used feature. At the end of 2015, there were a total of 7.2 billion mobile subscriptions globally (ITU, 2016). The report of Deloitte (2013) indicates that globally, the daily SMS volume is more than 20 billion messages, which is roughly three messages per subscription.

As Hong et al. (2008) observed, consumer adoption of the service is more rapid when there is social effect involved. From a consumer perspective SMS can be seen as a disruptive innovation because there was no mobile messaging solution available before SMS and introduction enabled people to communicate while on the move. Consequently, the adoption rate of mobile handsets with the SMS feature grew quite rapidly.

The second use-case is messaging between a user and a machine, and the third use-case is vice-versa. As described in Section 5.3, there is abundance of different SMS based services available nowadays. From a user perspective, SMS is a disruptive technology. Actions, for instance visiting a service point or sending traditional snail mail, took a lot of time earlier and can now be carried out within seconds using SMS. These SMS based services have changed consumers' behaviour radically. Anymore, traditional service models are seen as unattractive by consumers and those traditional service providers become disrupted in several industries.

The fourth model is purely machine to machine without any user intervention. The example mentioned in Section 5.3, electricity consumption metering, has also changed consumers' behaviour. Now consumers can monitor their electricity consumption almost in real time and optimize their usage. However, most of these services are such that the user does now know or does not care if the company is using SMS.

5.5 Regulation

It is well known that regulations and legislations are established to fix problems in the market. This is also the case with SMS regulation. During the early phase of SMS, there were some issues that forced regulators to intervene.

For instance, in Finland in the late 90s, several customers accumulated huge bills by ordering SMS based ringtones and other special services without knowing how much the services cost. These issues were created due to an absence of separate service numbering for specially priced services. As a consequence, users were unaware if the service they were utilizing was using standard or special SMS service pricing. Hence, the telecommunication regulator authority decided to introduce SMS service numbers as a solution to overcome these issues that SMS had generated. At the time of this study, there are more than 1,300 individual service numbers in use in Finland. (Rakkolainen, 2016)

However, traditional regulatory actions have not prevented all SMS related problems from occurring (Edita, 2016). For instance, in Finland, there are several court cases where SMS has played some kind of role in the lawsuit. Furthermore, public authorities such as the Finnish consumer ombudsman have published several SMS related policies to steer the market into the right direction. The time-series of those different court cases and policies can be seen in Figure 3-d.

On the other hand, the European Commission (EC) has instituted regulations that lower the roaming charges between countries. These regulations acts have changed the industry architecture in the telecommunications industry within Europe. For instance, regulations regarding roaming on public communication networks prompted national regulators in 2012 to adapt policies that set cost based tariffs between operators (E.C., 2016). After that, the EC set even more stringent roaming tariffs regulations. Tariffs will decrease gradually, and eventually, starting June 2017, sending and receiving an SMS in a roaming network within the EU will cost the same as in the home network. Hence, these regulatory measures disrupt network service providers' SMS market.

5.6 Social Order

The top layer in the disruption model, the social layer, represents the entire society's social order. However, dynamics of the social structures are well beyond the scope of this study. Nevertheless, there are some cases where SMS has had some kind of clear role regarding social order.

For instance, some governments use SMS services to announce a state of emergency for citizens. These include such announcements as severe weather condition, terrorist attacks, traffic alerts and gas leaks. Obviously, the reason for these announcements is to keep citizens safe. Furthermore, in some nations, governments restrict citizens' freedom of speech. SMS has enabled these people to communicate more freely, exchange ideas, form social groups, and possibly cause a revolution.

The collected statistics can provide indicators of the timing of different events during the disruption process. Figure 4 illustrates a normalized time-series of the statistics seen in Figure 3. It can be seen that the first item to emerge was scientific publications, the second item was patents, the third item was service numbers and the last item was court decisions. The order is the same as the order of the layers in the disruption framework. However, the order of reached maximums does not follow the same order. The first to decline was patents, the second to decline was service numbers, the third to decline was publications and the last to decline is court decisions.

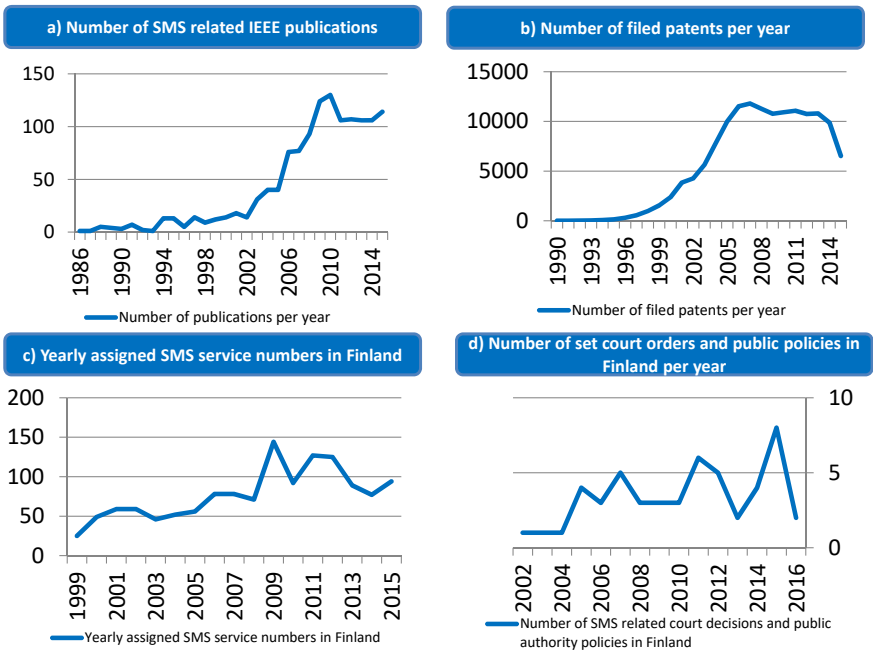


Fig. 3. Statistics related to SMS from different layers of the Disruption Framework

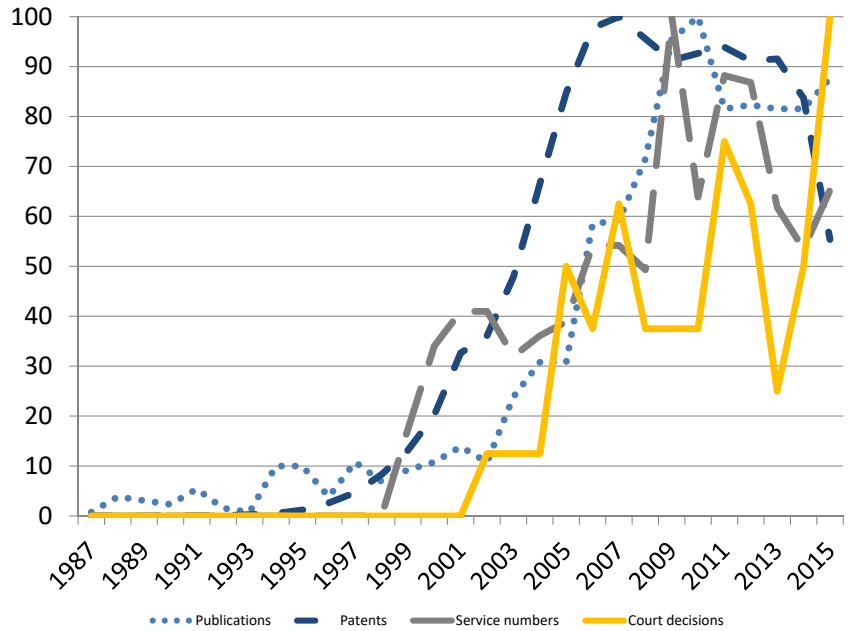


Fig. 4. Normalized time-series of different statistics

6 Results

SMS was not the first text messaging service on the market. Telex, fax, etc. (Trosby, 2010) were widely used for decades before SMS. However, those options did not offer mobility. SMS introduced mobility for both senders and receivers. Predecessors required separate devices on both ends, while in SMS a typical mobile handset provides all required functions. Standardization bodies and network equipment manufacturers were able to leverage old knowledge inherited from analogue technologies. In that sense, SMS can be regarded as a technology that disrupted previous messaging services.

Today, completely new industries have been born that leverage SMS, especially in the M2M area. SMS has been a disruptive innovation mostly for consumers, but certainly, it has also been disruptive for service businesses.

Events during the history of SMS can be separated into two distinctive categories: a) Industrial applications related events that created the pathway for M2M type applications. Figure 5-a illustrates that timeline. b) Consumer applications related events created the pathway for those applications that are human interactive type. Figure 5-b illustrates the timeline for these events. Both of these paths began in the early 80s and the pathways started to diverge in the 90s.

However, there are some indications in both of these cases that other emerging technologies have already started to disrupt SMS ecosystem agents. Those replacement services started to emerge in the late 2000s.

The success of SMS has also been the cause of its eventual doom. Some handset vendors have implemented proprietary SMS solutions in their ecosystem, e.g. iMessage in Apple IOS based devices. These Internet based proprietary services are bypassing network service providers' SMS centres and billing systems, thus, users of that ecosystem are able to communicate without extra cost. Furthermore, other proprietary Internet based messaging solutions are disrupting SMS as well: for instance WhatsApp, Facebook and WeChat. These new applications have significantly decreased network service providers' revenues. On the M2M side, IP packet based technologies are replacing SMS based applications on some new implementations.

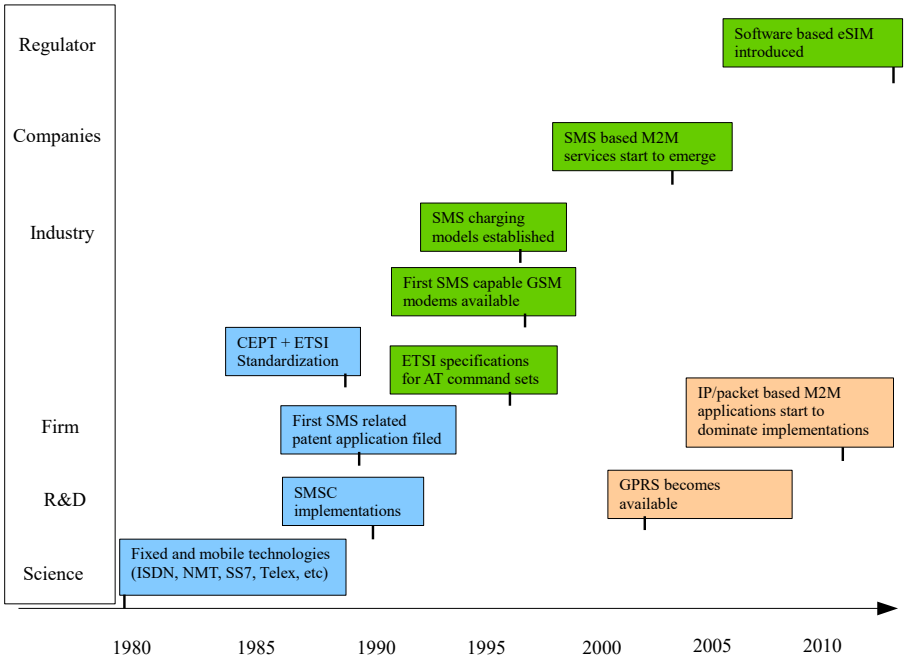


Fig. 5-a. Industry applications related events on the timeline on the different layers of the Disruption Framework

Although the presented disruption model does not mandate any rate of adoption for a disruptive event, it can be assumed that only relatively fast changes in the ecosystem can cause such discontinuity that some agent perceives it as disruptive. One way to measure the rate of the change is by using the diffusion model (Rogers, 2003). For instance, Andersson and Hedman (2007) studied diffusion of advanced mobile services, including SMS, in Swedish companies in 2006 and observed that adoption of the SMS service was rather slow. On the other hand, there is a common trend when we compare observations made by Andersson and Hedman (2007) with the statistics seen in Figure 4. Before the mid-2000s the numbers of patents, service numbers, court cases and published papers were relatively low but after the mid-2000s all of these numbers have grown significantly. This indicates that the innovators and early-adopters' phases were timing before the mid-2000s, at least for SMS based services. The majority phase approximately started in 2006.

There are some clear cases where companies have changed their strategies to leverage SMS on an alternative business domain. For instance, SMS is widely used in the marketing industry (event B). At the same time, some traditional marketing firms have been put out of business (event D) because their paper-based advertisement model no longer attracted companies' attention. A second example, mentioned earlier, is Apple's iMessage service. The mobile handset manufacturer entered the SMS arena by capturing all messaging between Apple devices and preventing operators from charging for the traffic (event A). This action forced operators to shift their focus on to more value generating services such as mobile data plans and over-the-top (OTT)

video services (event C). However, there are new entrants in the field (event E). For instance, Google has introduced their global mobile subscription service that includes unlimited SMS service. The illustrative diagram can be seen in Figure 6.

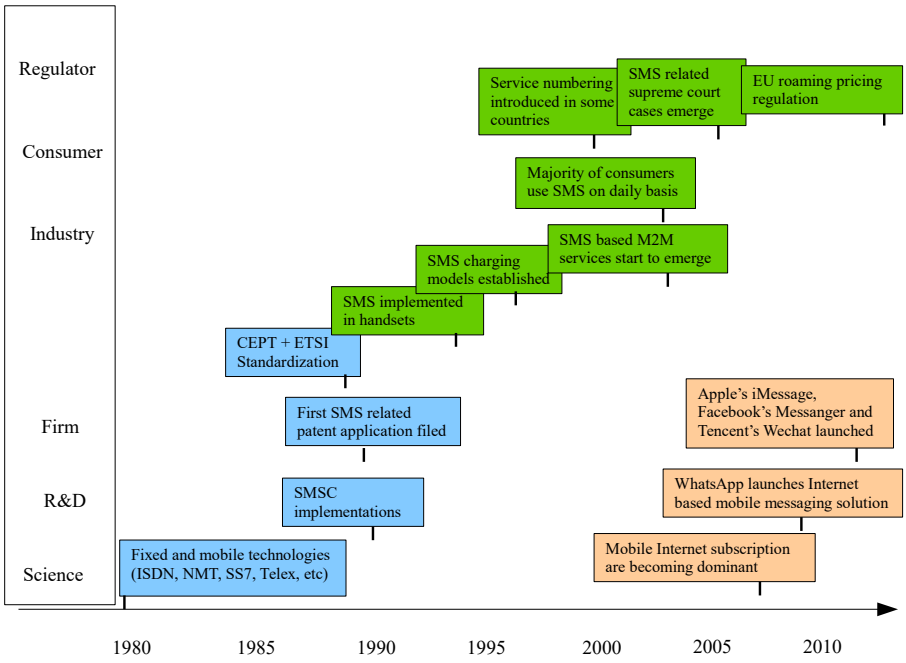


Fig. 5-b. Consumer applications related events on the timeline on the different layers of the Disruption Framework

7 Discussion

This paper contributes practically and theoretically to modelling of disruptive innovations. Pragmatically, the assessment of SMS using the Disruption Framework reveals the process of how SMS has diffused into the different layers of the ecosystem and how different industry stakeholders have experienced this process. Regarding theories, there are two views. First, SMS can be used as a qualitative indicator that there actually is a real world application that fits into the Disruption Framework theory. The framework was found to be accurate enough to be used for modelling a dynamic process of innovation diffusion and then to identify events that are either low-end disruptions or new-to-the-world innovation based disruptions. Second, by defining the term disruption from an agent-based view, this theory builds a foundation for more advanced ecosystem modelling.

One aspect of technology disruptiveness is whether or not it is a competence-enhancing or competence-destroying (Anderson, 1990) innovation. In the case of SMS, there are indications that the base core technology behind SMS, the GSM, is actually competence-destroying. GSM standards are based on digital technologies

rather than analog technologies. Control-plane programmability allows for introducing new features to the network by upgrading standards, mobile core and handset software. Palmberg and Martikainen (2005) discuss why Nokia, as a network equipment manufacturer, was able to succeed. They also observed that most of the competencies that were required in NMT need to be replaced in GSM technologies. Hence, this indicates that SMS was seen, together with GSM, as a disruptive technology for network equipment manufacturers.

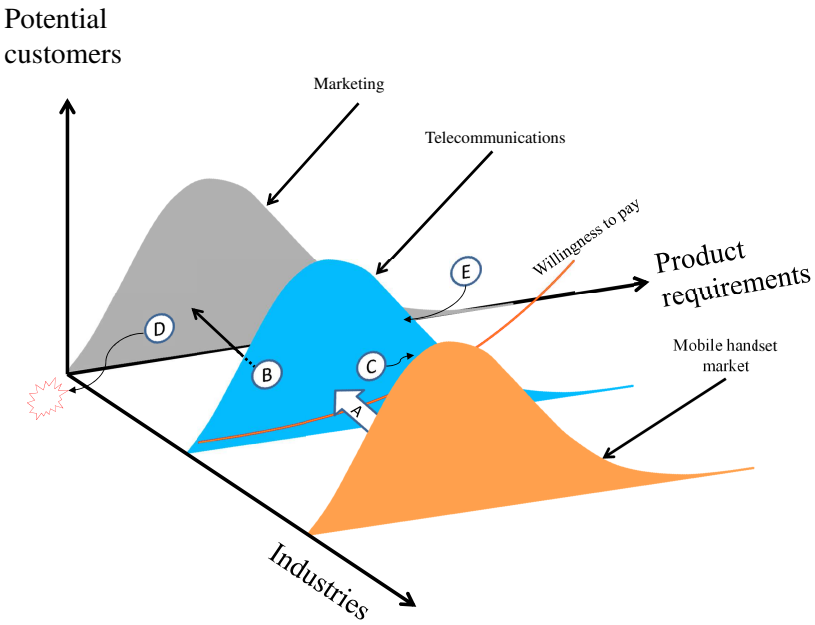


Fig 6. Technological diffusion from an industry to another (after Kilkki et al., 2017)

In conclusion, the disruption framework is useful when applied to the ecosystem of some wider phenomena. Examples presented in this paper are just indications of compatibility to the framework. The model can be used for modelling the process that may lead to a disruption. The model can also be used to understand temporal dimension of the technology diffusion within an ecosystem.

This study also contains some limitations. This study was carried out in Finland and all interviewed persons were Finnish although they all have international industry expertise. One way to improve the scope of the study would be to include interviewees from several different regions. Furthermore, there were only three industry experts interviewed to support the literature study. It is obvious that if more persons were interviewed it is likely that some other viewpoints would be addressed.

Acknowledgement. The authors would like to thank all interviewed persons. This study was carried out together with The Digital Disruption of Industry (DDI) –project which is funded by the Strategic Research Council (SRC) at the Academy of Finland. SRC provides funding to long-term and programme-based research aimed at finding solutions to the major challenges facing Finnish society.

Interviews.

Timo Ali-Vehmas, Nokia, Helsinki

Interviewed on 19.8.2016 by J. Lähteenmäki

Petri Pöyhönen, Nokia, Helsinki

Interviewed on 6.9.2016 by J. Lähteenmäki

Jukka Rakkolainen, Finnish communications and regulatory authority, Helsinki

Interviewed on 1.9.2016 by J. Lähteenmäki

9 References

Anderson, P. & Tushman, M. L. (1990). Technological discontinuities and dominant designs: a cyclical model of technological change. Administrative Science Quarterly, 35(4), pages.

Andersson, B. & Hedman, J. (2007). Diffusion of advanced mobile services: a survey of large swedish firms. løbenummer: 075483.

Balston, D. (1989a). Pan-european cellular radio: or 1991 and all that. Electronics & Communication Engineering Journal, 1(1), 7–13.

Balston, D. (1989b). The impact of customer mobility. In Changing face of telecommunications transmission, iee colloquium on (pp. 2–1). IET.

Bonabeau, E. (2002). Agent-based modeling: methods and techniques for simulating human systems. Proceedings of the National Academy of Sciences, 99(suppl 3), 7280–7287. doi:10.1073/pnas.082080899.

Christensen, C. M. (1997). The innovator's dilemma: when new technologies cause great firms to fail. Boston, MA, USA: Harvard Business School Press.

Deloitte. (2013). Short messaging services versus instant messaging: value versus volume. Retrieved from http:/ / www2 . deloitte . com / content / dam / Deloitte / au / Documents / technology - media - telecommunications /deloitte - au - tmt - short - messaging - services - versus -instant - messaging - 011014 . pdf / hitachi - white - paper - separating-hype-from-how

E.C. (2012). European Comission: Regulation (eu) no 531/2012 of the european parliament and of the council of 13 june 2012 on roaming on public mobile communications networks within the union text with eea relevance. Retrieved: http://eur- lex.europa.eu/legal- content/EN/TXT/?uri=CELEX:32012R0531

Edita (2016). Edita Publishing Oy, Edilex. Retrieved from https://www.edilex.fi/

Ficora (2016). Finnish Communications Regulatory Authority. : The number of sent text messages. Retrieved from https : / / www. viestintavirasto . fi / en / statisticsandreports/statistics/2013/textmessages.html

Ficora (2016-a). Finnish Communications Regulatory Authority. Myönnetyt lyhytsanomapalvelunumerot. Retrieved from https://www.viestintavirasto.fi/internetpuhelin/puhelinverkonnumerointi/lyhytsanomapalvelunumerotsms/myonnetytjavapaatlyhytsanomapalvelunumerot.html

Google (2016), Google Patents index. Retrieved from https://patents.google.com/

Huusko (2009), Uusi Suomi, Retrieved from: https://www.uusisuomi.fi/raha/74670-lipponen-%E2%80%9Dnokian-tarina-sepitetty%E2%80%9D

Hong, S.-J., Thong, J. Y. L., Moon, J.-Y., & Tam, K.-Y. (2008). Understanding the behavior of mobile data services consumers. Information Systems Frontiers, 10(4), 431. doi:10.1007/s10796-008-9096-1

IEEE (2016). IEEE Xplorer publication archive. Retrieved from http://ieeexplore.ieee.org/Xplore/home.jsp

ITU (2016). International Telecommunication Union: The key 2005-2016 ict data for the world, by geographic regions and by level of development. Retrieved from http://www.itu.int/en/ITU-/Statistics/Documents/statistics/2016/ITU_Key_2005-2016_ICT_data.xls

Kilkki, K., Mäntylä, M., Karhu, K., Hämmäinen, H., Ailisto, H. (2017). A Disruption Framework, to be published 2017.

Makkonen, M. (2015). Sms-viestien läpimurto. Retrieved from http://suomidigi.fi/wp-content/uploads/2016/03/digih_smsviestit.pdf

Manninen, A. T. (2002). Elaboration of NMT and GSM standards: From idea to market. University of Jyväskylä.

Markides, C. (2006). Disruptive innovation: in need of better theory. Journal of product innovation management, 23(1), 19–25.

Palmberg, C. & Martikainen, O. (2005). The gsm standard and nokia as an incubating entrant. Innovation, 7(1), 61–78. doi:10 . 5172 /impp. 2005. 7 . 1 . 61. eprint: http : / /www.tandfonline.com/doi/pdf/10.5172/impp.2005.7.1.61

Ritala, P. & Aarikka-Stenroos, L. (2016). Disruptive innovation in ecosystems: path-creation and institutional barriers. In Ispim innovation symposium (p. 1). The International Society for Professional Innovation Management (ISPIM).

Rogers, E. M. (2003). Diffusion of innovations (5th). New York, NY [u.a.]: Free Press.

Schmidt, G. M. & Druehl, C. T. (2008). When is a disruptive innovation disruptive? Journal of Product Innovation Management, 25(4), 347–369.

Telia Company (2017), The Pioneers, Retrieved from: http://www.teliacompanyhistory.com/Global/Documents/ThePioneers.pdf

Trosby, F., Holley, K., Harris, I., & Hillebrand, F. (2010). Short message service (sms): the creation of personal global text messaging. John Wiley & Sons.

Journal of Innovation Management
JIM 5, 3 (2017) 140-155
HANDLE: http://hdl.handle.net/10216/107952
SM: Apr/2016 AM: Aug/2017

Fish farming on the moon: Innovations countering professional and conventional ways

Mary Genevieve Billington[1], Katja Maria Hydle[2]

[1]University of Stavanger, 4036 Stavanger, Norway; [2] International Research Institute of Stavanger, Oslo Science Park, Gaustadalleen 21, 0349 Oslo, Norway

mary.genevieve.billington@uis.no, katja.hydle@iris.no

Abstract. Innovations that counter professional and conventional ways meet barriers to acceptance in communities of experts. How small businesses meet and seek to overcome these barriers may determine the ultimate success of their innovations. A collective case study of 32 firms involving 40 innovation projects revealed that this initial opposition from scientific and professional groups may overwhelm entrepreneurs. Entrepreneurs lack strategies to deal with and move beyond this opposition to gain entry and acceptance in professional communities. Interpreting the findings through the lens of practice theory, we find that entrepreneurial practices pose challenges to professional practices, to professional authority, to accepted methods and to the imagination. Successful entrepreneurs demonstrate flexibility, aligning their practices to the practices of the professional groups. Mutual alignment of practices will serve both entrepreneurs and professions.

Keywords. Innovations, Practices, Entrepreneurs, Professional, Barriers

1 Introduction

For both small and large firms, failure to receive acceptance in professional communities may make commercialization of ideas difficult, or even impossible, thus thwarting innovation processes. This paper explores how innovations characterized by a high degree of novelty encountered barriers to acceptance in professional communities. The reported barriers, which we term "professional opposition", emerged through the analyses of interview data collected in a multiple case study, involving 32 small firms and 40 innovation projects. Although almost all of the projects studied achieved verified technical success, only seven of these projects had achieved business success, at the time of interview.

The paper seeks to analyze the nature of the particular barriers of "professional opposition". To understand the barriers, we allude to literature on the nature of professions, though this is not the focus of the paper. We seek both to access the nature of the barrier and to assess the importance of the barrier for the innovation process. In so doing, we respond to calls by both Doern (2009) and Parry (2010) and try to unpack a specific barrier that appears to be of significance to the firms in our study. In order to identify how entrepreneurs perceive and meet these barriers, we focus on socially embedded activities that are altered or challenged. We construct four portraits types to describe how entrepreneurs perceived the opposition to the innovation: challenging professional consensus, challenging professional authority, challenging accepted

ISSN 2183-0606
http://www.open-jim.org

methods and challenging the imagination. The findings confirm the trans-disciplinary nature of innovation practices and the importance of social processes in these practices (Kerosuo, Kajamaa, & Engeström, 2010). Our theoretical contribution is the development of practice theory in understanding how practices emerge. The findings also provide practical direction for managers and entrepreneurs who may encounter professional opposition and in addition, further the understanding of the nature of the professions.

2 Theoretical background and framing

2.1 Professional ways

We adopt a broad view when referring to professions and professional ways (Mieg, de Sombre, & Näf, 2013). We see professional boundaries as fluid (Brante, 2011; Saks, 2012), and refer to emerging and open professions, such as engineering, bio-chemistry and so on, rather than the classical closed "status" professions (Brante, 2011; Saks, 2012) such as the legal or medical professions, which are governed by codes of ethics and legislation. In line with Brante (2011, p. 17), we see professions as "occupations conducting interventions derived from scientific knowledge of mechanisms, structures and contexts", but while being based on a specialized scientific education is a precondition for a profession it is not sufficient (Saks, 2012). Professions are formed by social factors (Gherardi & Landri, 2014), shaped by context and are space and time dependent. Professions undertake self-regulations regarding organization, moral imperatives, control devices, collegiality and so on (Brante, 2011). Professionals often rely on intuition and on prior experience rather than on scientific theory. Eraut (2000) confirms the significance of tacit knowledge for professional work. Such tacit knowledge, or knowing (Gherardi, 2001), may be a source of competitive advantage, sustaining effective established ways of working that are difficult to emulate. However, it may also function as a conservative rather than innovative force, maintaining old practices and rejecting new, even when these practices are contradicted by fresh or improved scientific knowledge (Gourlay, 2006). Munro (2010) investigated how belief contradicting scientific information elicited resistance processes, and was often perceived as a threat to self-image. The new information produced cognitive dissonance and informants often responded by discounting the scientific method. Reliance on a collective tacit knowledge, expressed in strongly held ideologies, traditions and routines or more simply "the way we do things" is a hallmark of professions.

Collaboration often requires the opening of professional boundaries. Pfeffer and Sutton (2006) point out that, practitioners often prefer to rely on established professional wisdom and their own experience, and embrace only evidence that fits their own strengths. Alternatively, they may look to high performers and mimic these, rather than support lone geniuses or gurus. In general, practitioners are suspicious of breakthroughs, as these are rare.

Stringfellow, Shaw, and Maclean (2014) investigate how small firms, without a record of solid past performance, seek to acquire and maintain "legitimacy" from the professional field. Legitimacy originates from social judgment and concerns the acceptance, appropriateness and desirability of an entity to the norms and values of the

social context. They found that firms adopting a habitus, which was at odds with the dominant dispositions of the field, failed in acquiring legitimacy and were subsequently, denied access to resources. Thorpe, Gold, Holt, and Clarke (2006) found that entrepreneurs need to develop "maturity" through interaction with mature-others to survive and grow. Entrepreneurs develop maturity through embedding their ideas within the wider economic and social activities of their community. These processes however, demand access to appropriate networks.

The insights discussed provide a background for understanding the complex social processes underlying the barriers, which professions raise when introduced to innovative ideas, and processes.

2.2 Innovation management and barriers to innovation

Understanding and managing innovation processes, by identifying enabling and constraining mechanisms, is essential for successful business development (K. B. Kahn, Barczak, & Moss, 2006; Kenneth B. Kahn, Barczak, Nicholas, Ledwith, & Perks, 2012). In general, innovation research sees alliances, partnerships and collaborative constellations between organizations as enabling mechanisms for innovation (Beers & Zand, 2014; Huang, Chung, & Lin, 2009; Lin & Wu, 2010; Musteen & Ahsan, 2013; Narula, 2004; Teirlinck & Spithoven, 2013; van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009). In product development, collaboration with external partners on innovation activities augments the performance of the firm (Beers & Zand, 2014). In our study, we look particularly at the barriers, which entrepreneurs experience when they seek partners and collaborators amongst those already established within the field. These barriers may be perceived and/or real.

Doern and Goss (2013) note that while studies listing perceived barriers abound, these studies tend to depict barriers as static objective obstacles rather than as socio-emotional processes. Social barriers may include forms of discrimination, forms of social exclusion, corrupt financial practices and conflicts in inter-personal relationships. In a study of Russian entrepreneurs, Doern and Goss (2013) analyzed the power rituals occurring when entrepreneurs meet hostile institutional environments and bureaucracies that deny them access to funding and other support. Entrepreneurs reported experiencing a context of unequal resources, where they had little scope to influence the outcome and little trust in the motives of the other party. Entrepreneurs responded with three different strategies: open resistance, reluctant acquiescence and withdrawal. In a study of small manufacturing firms, Freel (2000) found that lack of trust and an inability to identify suitable partners are principal barriers to collaboration. Considering barriers as socio-emotional processes is critical when analyzing how professionals react to innovative ideas and how innovators react to initial negative responses from professional communities.

2.3 Entrepreneurial practices

The issues of understanding how entrepreneurs innovate and how they build appropriate networks with exiting communities are addressed in different theory streams. Accessing appropriate networks and building partnerships is one of the three principles in entrepreneurial effectual theorizing (Sarasvathy, 2001, 2009). It stands

alongside finding ways to reach the market with a minimum of resources and turning the unexpected into the profitable. Effectual reasoning begins with a set of means while the goals emerge over time. This reasoning is fundamentally different from casual reasoning which begins with a pre-determined goal and given means, and seeks to identify the optimal way to realize the stated goal (Sarasvathy, 2001). Entrepreneurial effectuation theorizing thus explains how and why entrepreneurs are entrepreneurial; as opposed to managers and strategists. Entrepreneurial effectual theorizing believes in a future that is shaped by human action (Sarasvathy, 2001). Entrepreneurial effectuation thus rests on ontological individualism, which claims that social life is an aggregate of the actions of individuals. However, it cannot be claimed that all social phenomena are constructed of individuals and their relations. There is something beyond individuals that needs to be explained (Schatzki, 2005). Social ontologies, and specifically practice ontology, offers a way to grasp and understand activities that are performed by multiple people; social phenomena are rooted in practices (Schatzki, 2005). Understanding entrepreneurial practices builds on Johannisson (Johannisson, 2011, 2012; Steyaert & Landström, 2011), and connects the understanding of entrepreneurship to the practice turn in social sciences (Schatzki, Knorr Cetina, & von Savigny, 2001). This tradition depicts entrepreneurship as "the ongoing practice of creatively organizing people and resources according to opportunity" (Johannisson, 2011, p. 137).

In practice theory, as developed by Schatzki (1997, 2002, 2005, 2006, 2012, 2013; 2016a, 2016b; 2001), practices are understood as a set of organized activities, and these activities are in turn composed of different actions. Activities reflect the contexts within which these are performed. Practices are thus situated. By viewing the entrepreneurial action that forms activities, and how these activities in turn form practices, we emphasize the socially embedded and situated nature of entrepreneurship.

In this paper, we use practice theory as a lens to illuminate the nature of particular barriers experienced by entrepreneurs when promoting the initial innovative idea to potential external collaborators. De Clercq and Voronov (2009) uncover how activities of conformity reinforce existing practices and institutions, while activities of change transform existing practices (De Clercq & Voronov, 2009). De Clercq and Voronov (2009) claim that institutional reinforcement is related to professionalism, where members are sensitive to normative organizations, upholding what is prescribed, adhering to what is known as acceptable and being in line with regularities (Schatzki, 2012). We wish to go further, by questioning how professional practices appear to emerge and persist when challenged by entrepreneurial innovation.

According to practice theory (Schatzki, 2012), human activities are not predetermined, and activities are subject to new starts and changes in directions that may be surprising or unexpected. Schatzki explains how activities are laden with the past: "Past practice organizations circumscribe present activity, people react to and act in the light of past states of affairs, and the bodily actions that publicly manifest performances reflect bodily repertoires and practical understandings that are left behind by past activity and experience. Activity is circumscribed, induced/oriented, and given public presence by the past" (2010, p. 214). Thus, the pasts of practices induce their emergence and persistence. This understanding of the emergence and persistence of practice allows us to interpret how novel innovations as presented through entrepreneurs are met by professional communities; "what people do, how they react to things, is circumscribed,

oriented, and given public presence by or through the past" (Schatzki, 2010, p. 215). Practice emergence may stem from different components, which in turn brings us back to what practices are. Practices are organized activities that are composed of, i) practical understandings (bodily actions), ii) rules (directives, procedures), iii) teleological structures (acceptable ends) and iv) general understandings (senses of the worth) (Schatzki, 2012, 2013). The *emergence* of practices relates to the development of these practical understanding, to rules, to teleological structures or general understandings. However, there are other ways in which practices may emerge, such as through the introduction of new material entities that require new practices, or when particular individuals, such as entrepreneurs, depart from a situation and start anew, through a "line of flight" (Schatzki, 2013, p. 38).

We use practice theory as a lens to investigate more closely the meeting between entrepreneurial practices and professional practices. The research questions we consider are: How do entrepreneurial practices appear to challenge professional practices? How do specific professional practices oppose innovation in SMEs? In answering these questions, we illuminate particular practices in both product development and in professional communities. We further highlight the different challenges arising and the barriers which need to be overcome if innovation processes are to succeed.

3 Method

3.1 Approach and sample

The data analyzed in this paper stems from a collective case study of 40 innovation projects in 32 firms, in the county of Rogaland, Norway. The sampling was purposeful (Silverman, 2005). Each of the projects in the study had received funding through a regional innovation initiative "The Programme for Regional R&D and Innovation" (hereafter VRI) in the period 2008- 2012. The VRI programme was designed and funded by the Research Council of Norway but is implemented regionally, in all counties in Norway. VRI offers support to firms and networks engaging in innovation. One of the support mechanisms is a grant of up to 33000 euros earmarked collaboration with a research institute. Rogaland County awarded these grants primarily to small and medium sized enterprises (SMEs)[1]. In accordance with the VRI design, the county selected firms from target industry sectors. In Rogaland, these sectors were Energy, Food, Maritime and Health. Each of these industries employs professionals within different disciplines; biologists, engineers chemists and could thus be described as a professional field (Brante, 2011). In carrying out the case study, we attempted contact with all firms that had received grants, in the four-year period, approximately 120 firms. However, some firms had been dissolved, others had moved location, and still others were unavailable for interview for various reasons. The final sample consisted of 40 projects in 32 firms. The final portfolio was characterized by diversity; project goals

[1] The Research Council of Norway defines SME as firms with "*less than 250 employees and a yearly turnover under 50 mill. Euro or a balance 43 mill. Euro (or both)*"

ranged from developing new methods of growing strawberries to the design and construction of tidal windmills. The majority of the projects stemmed from the energy and food industry reflecting the industrial profile of the region. The entrepreneurs categorized their innovation projects as incremental, radical or quantum step. The projects were predominately stand-alone technological product innovations. Table 1 presents an overview of the projects in the study

Table 1. Overview of projects in the study.

Target Sector	Projects	New product development	Start– up	Single target	Incremental/radical/ quantum innovation		
Energy	18	17	12	11	7	8	3
Food	19	18	12	15	10	8	1
Maritime	2	2	2	2	1	1	0
Health	1	1	1	1	0	1	0
Total	**40**	**38**	**27**	**29**	**18**	**18**	**4**

The object of the original study was the innovation project from the idea to very commercialization. To this end, we supplemented interview data with comprehensive document study. However, in this paper, we focus on the interview data. We conducted semi-structured interviews either with the entrepreneur in the case of start-ups or with the person in charge of the innovation project. Each interview was of one to two hours' duration. The interviews were audio taped and transcribed.

3.2 Analysis

The theory development and research process may be viewed as similar to mystery construction, involving a critical dialogue between the theoretical framework and the empirical material (Alvesson & Kärreman, 2007). In the analysis, we followed the approach of Alvesson and Kärreman (2007) employing the inference mechanism of abduction. Abduction consists of three steps: applying a theory or established theoretical rule, being surprised by empirical phenomena, and articulating a new theory resolving the surprise. Alvesson and Kärreman (2007, pp. p. 58-60) address this process through reflexivity, sensitive constructions and interpretive repertoires.

Our initial intention was to identify the barriers encountered by firms during the innovation process, on the path towards commercialization. We analyzed the empirical material in-depth, referring to relevant theory (Alvesson & Kärreman, 2007). Three barriers, commonly identified in earlier research are: lack of time, lack of money and lack of people (competence/skills) (Kaufmann & Tödtling, 2002). While the firms in our study reported these same barriers, a less tangible barrier emerged consistently from the data. This less tangible barrier can be explained as a surprise or puzzle (Alvesson & Kärreman, 2007). Such a puzzle is understood as a breakdown in our understanding where empirical findings cannot be explained by existing theory (Alvesson & Kärreman, 2007). The barrier, which we termed "professional opposition", represented a breakdown in our existing understanding, demanding attention.

In coding the interview data, "Professional opposition" was an extended code, describing negative reactions to the innovation by external parties, expressly those

parties with recognized professional expertise in the field of the innovation, as reported by the entrepreneur. These external parties were potential collaboration partners: competitors, suppliers, customers or scientists in research institutions. A limitation and possibly a provocation for external parties was that the innovators often sought to sell their ideas without offering detailed explanations, being afraid that others might steal the idea. An innovator explains his position in this way:

> *"I have been paranoid; felt that I had to have a patent before I could talk … it was important for me", (oil pressing project).*

Potential stakeholders may thus be operating with imperfect information and therefore be more likely to rely on prior beliefs and understandings. (Hall, Bachor, & Matos, 2014).

We understand the concept "opposition" to represent a phenomenon, a reaction experienced by the entrepreneurs and innovators (Corbin and Strauss 1998) and illustrate with the following quote from a project manager:

> *"… if we had listened to everyone, we would have stopped all this a long time ago. And some of those who have supported the project also slaughtered it in the beginning and because they slaughtered it we had to find explanations and we put the numbers into formulas and we got positive results and these conflicts have been the most important learning points we have had really and the most important competence has come from these conflicts", (renewable energy project).*

The entrepreneur clearly describes a negative reaction from the professional field, and how the reaction provoked a response, on his part. In this instance, the encounter strengthened his practice. This constructive response extends the repertoire of responses, as reported by Doern and Goss (2013). In general, the objections recorded related to the perceived technical feasibility of the innovation expressed in phrases such as "it won't work" or "it is not how we do it". Objections to the economic viability of production and marketing of the innovation, expressed phrases such as "it won't pay" or "it is too risky", were not coded as professional opposition. These were not prevalent in the data material.

4 Findings

One distinguishing feature of "innovation" is novelty (Slappendel, 1996), and it is precisely this *novelty in practice* which appears to challenge professional practices and provoke an oppositional response. In the subsequent analysis, we seek to unfold the perceived response "professional opposition".

Our interpretation is that the practices of the entrepreneurs contested professional practices. Professional practices are established ways of doing things that express the norms, values, visions of the professional community. From the analysis of the coded data, we constructed the following typology:

- Challenges to professional consensus
- Challenges to professional authority
- Challenges to accepted methods

- Challenges to the imagination

We discuss each of these giving illustrative examples from a number of projects. In all 33 of the projects reported these less tangible types of barrier. Many projects reported experiencing more than one type of challenge. Obtaining a deeper and more analytical grasp of the nature of the initial professional response, provides a basis understanding of the demands on entrepreneurial practices. Entrepreneurs need to develop ways to respond rationally rather than emotionally to professional communities.

4.1 When innovative practices challenge professional consensus

Challenges to professional consensus were those instances where the innovation flouted accepted professional knowledge in the area of the innovation. The first case we describe is in the Energy sector and concerned the production of renewable fossil free energy through the combination of two well-recognized and established technologies, as described by the innovator:

> *"…the process is well known and an old process really, but using the technology in this way is totally new", (alternative energy project).*

The innovation is a technical success and is well on the way to commercialization with industrial partners now committed. When asked about what had been most difficult in the process, the innovator answered:

> *"…personally, it has been economy, but the most difficult for us has been to get acceptance for* ***this that*** *physics wins over professional theory. It has been difficult to get acceptance for this. It is easy to think of professional know-how, the way we do things, is what counts, but when this comes in conflict with basic physics then something is wrong somewhere and it has to be accepted," (alternative energy project).*

The innovator explained that his own professional background was inadequate and he need to learn more:

> *"I was a psychologist…I had to take a physics course after I started this and that was lucky too because all Norwegian trade books say that it can't be colder *(*reference to technical issue that is at the core of project). What is important here is to not to have a professional education but to understand physics," (alternative energy project).*

This conflict, with professional knowledge and understanding, made it difficult for the innovator to receive monetary support from various sources. Professional experts evaluated his applications and consistently rejected his ideas. He used "*a lot of energy*" trying to convince people. He was fortunate and found a physicist who was willing to listen to him and to test out the idea. Together they were able to develop a scientific platform for the innovation that proved acceptable to professional expertise. The physicist also represented professional authority. "*Sam, the physicist, he was critical at first but now he is on board*."

Another case in the study where professional consensus played in was the development of a system to "deactivate" salmon lice with electrical impulses, causing the parasite to fall off the salmon. The generally accepted view is that "water and electricity don't mix" and as such, the idea generated extreme skepticism. As the project manager

explained:

> *"In 2011, Norway used over 3 billion NOK to fight salmon lice and salmon escape. And we can solve the salmon lice problem. We had the idea of using electric current. Seawater is highly conductive… It was a wild trial and we saw the reactions on the salmon lice at the first controlled test. We found out that it worked. We went to the industry, but since we had done the research ourselves, no one believed us. Electricity and seawater, they smiled and shook their heads. We had to verify what we had found out…In the aftermath, they told us that they had concluded quickly that we were either idiots or geniuses. Crazy idiots," (salmon lice project I).*

Eventually, the industry and research partners were convinced by the results of scientific tests. It is possible to establish electric fences in seawater installations and in this manner effectively neutralize salmon lice.

In both these cases, the professionals reacted defensively with non-analytical responses, initially rejecting the innovation idea, referring to professional consensus (Gourlay, 2006). In both cases the firms succeeded by aligning their practices further to the scientific practices of the professional communities.

4.2 When innovative practices challenge professional authority

In these cases, the innovators had generally developed a solid scientific platform, in one case investing over 100 million Norwegian kroner in scientific research:

> *"...It is very high quality; we have developed something no one else has, extremely high quality. Professional folk are wide eyed and they listen when we explain what we have done. This is a good product; we have come a long way," (energy technology for maritime industry).*

Despite this solid scientific foundation, professional communities responded with disbelief or suspicion. A typical response, as reported by the innovators, was:

> *"'We have been trying to do this for 25 years and we have not had any success and so come two amateurs and you do it in two years' …. well they would not invest," (oil pressing project).*

Many of the informants described industry as "conservative" and as "sitting on the fence". Another example was a project involving the recertification of materials stemming from oil platforms. This project challenged both professional authority and accepted methods.

> *"Recycling was the idea…We did not get any of the industrial players involved, nor politicians. It is so hard to turn an entire industry. There is a network of companies..." (metal recycling project).*

When innovative practices challenged professional authority, the smaller firms in the study often folded or gave up on their idea. Larger firms, on the other hand, had the economic resources to continue their practices pursuing ideas and bringing them to the market.

4.3 When innovative practices challenge accepted methods

In these cases, the introduction of the innovation had potential to dramatically affect the daily practice of the professional community. An illustrative example comes from a dairy project where farms have introduced milking robots. Established practice in the industry is to milk cows twice daily at regular times. The introduction of robots allows the cows to wander in for milking at will. Robots perform the milking operation. Cows decide! A diary producer in the pilot explains:

> *"For the farmer, the work day is completely changed. He has to read a lot of statistics. It is a different way of working. He does not need to get up at 7 am, and he can drive his son to football. We have received very good feedback. The flexibility and possibility for more social family life is important. And the work practices have also changed. Some (farmers) are very good at attending in the barn, to follow and observe the animals wander freely. It is a different way of working than when the cows are standing in the milking shed," (milk robot project).*

The farmers expressed concerns about the diffusion of innovation because it demands significant changes in husbandry practice. Without support in the diffusion process, the innovation could easily fail. Those responsible for the innovation concluded:

> *"We received positive feedback from the farmers, after they had received a lot of advice and help from the producers and from advisors. To participate in this project, the farmers had to pay, and for a lot of older farmers, the data from the robots became too much to handle. How satisfied the farmers were? … [it] goes both ways. The farmers need practical advice. We have received feedback on what they find challenging, what is hard to tackle and what they need more of. On this basis, we will design more courses and come up with suggestions for improvements. The farmers need to make it work; the farmers need to wander around among the cows and observe in a new way…" (milk robot project).*

Another example comes from a software project, which demanded reorganization of workplaces, breaking down existing barriers and demarcations between professions.

> *"With this software, everyone will have a creative role. It is very much like a work process. Now, people use time on making things available in Excel, instead of being a geologist. …. Today many professional disciplines are working each their way, while they work with the same data, resulting in duplication of data. It is teamwork without a team. We force a multidisciplinary approach. The user experience will reflect a work process which is hard to perform practically, without this tool," (software project).*

The trial company was hesitant about changing work practices and decided not to

participate in further development, despite initial interest in the idea. In such cases, the entrepreneurs had little recourse for action. One industrial player did decide to invest in the project.

4.4 When innovative practices challenge the imagination

The title of this paper "fish farming on the moon" refers to an actual project, sponsored by NASA, which we came across in our study. The project exemplifies projects that may encounter opposition because they challenge the imagination, the way we think, our expectations.

Returning to the salmon lice problem, a different project developed a salmon-like odor or scent, which would serve to attract the lice thus deterring them from the real salmon. The entrepreneur explains how he looked outside of the confines of his discipline:

> *"It is in the news almost every day, the problems and challenges in dealing with salmon lice, so I was sitting and thinking about what could be done. What is possible? I have read about chemo taxis, things tried in the research field … I am a marine biologist, with experience from livestock and environment. And when I meet new challenges I try to make connections, when searching through academic articles…" (salmon lice project II).*

> *"Actually, this is an alternative to kill salmon lice with chemicals. The method is to drive the lice to something else. The idea was to lure the salmon lice towards the odor of salmon and not to the real salmon," (salmon lice project II).*

The idea was successfully patented eventually, although by another firm.

Other projects in the study attempted to "trick" nature. An example is the steering of fish production by using artificial light to create the illusion of a longer spring and summer season.

> *"We try to fool nature and it hits back. Quality was not good enough… We have to keep working on more advanced techniques …trick them a bit more …both light and temperature …" (fish production project).*

Several other projects in this category cannot be described here, due to promised anonymity, but suffice to say these were "far out". The projects received support in a regional VRI innovation programme by convincing technical experts in the evaluation committees. Convincing collaborators was more difficult and one of the entrepreneurs took a step-wise or gradual approach, suggesting a less radical innovation as the first step.

5 Discussion and conclusion

This paper addressed the following research questions: How do entrepreneurial practices challenge professional practices? How do specific professional practices oppose innovation in SMEs. From the data, we constructed at typology to illustrate four ways in which innovative practices challenged professional practices. These were neither exclusive, nor exhaustive. Some innovators challenged established professional

consensus, the *why of professional practices*, the reason behind an understanding, where acceptance would involve altering professional understanding, rewriting textbooks and so on. Other projects challenged the authority of the professional, the *who of professional practices*; the innovators met closed doors since they were challenging experts, big players in the game. We also identified innovations that challenged accepted methods, being the *how of professional practices,* demanding the development of new everyday practices. Finally, several projects challenged the imagination; the vision of professional practices. These challenges concerned the *what*, i.e. what is possible to do.

Projects challenging existing the "why, who, how or what" should by definition be innovative, since these demand change to existing professional practice or provoke new practices. We thus identified four different ways in which established practices engage when confronted with changes in directions that are surprising. Each of these responses is oppositional but the responses are differently reactive in relation to whether the why, who, how or what is involved.

In practice theory, these nuances of reactive human behavior are neither established, nor explained. Schatzki (2013) claims that the past of practices induces their emergence and persistence, but does not elucidate the differences between practice emergence and persistence, in relation to the why, who, how or what is involved. Our empirical findings contribute to extend practice theory in relation to the notion of practice emergence. In this study, new practices emerged in both communities (professions and entrepreneurs). Schatzki (2013) also claims that the emergence of practices requires the re-organizing of the practices through the development of practical understanding, rules, teleological structures or general understanding, or in relation to new material arrangements (Schatzki, 2013). Our findings confirm that professional practices are inclined to remain relatively stable, when challenged. On the other hand, for new practices to be established or to emerge, these have to be developed through altering existing understanding. Practice emergence in relation to the *why*, involves convincing existing professional knowledge and authorities through exposition, scientific testing and proof. In relation to the *who*, innovators need a strong partner, resources or a strong reputation to be able to succeed with practice emergence. The *how* relates to changes in everyday practices where innovative solutions and new ways of doing emerge through experience by the actors over time. Practice emergence in relation to the *what* involves providing proof of possibilities. Change must be envisaged. Thus, practice emergence is differently emphasized in relation to convincing, partnering, experiencing or engaging in the new practices. These findings constitute a contribution to practice theories.

In this study, the innovator meets the professional community. The nature of "professions" is well discussed and documented. In some cases, the innovator overcame the negative response and the innovation process has proceeded on the way to commercialization and diffusion. In several cases, the innovation process has halted. In the majority of cases, the entrepreneurs did not have successful strategies to deal with the opposition encountered. Hawkins and Rezazade (2012) confirm Dewey's claim, that when individuals are exposed to new knowledge that does not confirm to their interpretative framework they may hold this knowledge in suspense while looking for additional support. All the projects in the study have achieved technical success,

verified by the research collaboration for which they received funding. It would therefore seem that the opposition did not have a basis in scientific research but rather in the established, norms, methods, and authority inherent in the professional community. A study of Norwegian entrepreneurship (Berglann, Moen, Røed, & Skogstrøm, 2009) indicated that the least entrepreneurial workers are to be found in the professions, amongst people with high educational attainment e.g. researchers (with PhD), nurses, social scientists and teachers. Perhaps it should not then be surprising that our innovators encounter opposition in their meeting with these different professions.

This paper explores barriers experienced by firms in the initial stages in the innovation process. One particular barrier, consistently reported by firms, was the barrier of professional opposition, encountered in various forms by innovators when introducing their idea to the professional community. To promote a deeper understanding of the practices of both the professionals and the entrepreneurs we have "unpacked" the barrier of professional opposition identifying four different types of challenge. This understanding may guide the formation of appropriate strategies for SMEs and entrepreneurs to introduce new practices.

The findings have implications for innovation management and for the development of the professions. For the professions, there may be distinct advantages in developing a culture of openness and on-going learning. A study by Burcharth, Knudsen, and Søndergaard (2014) indicates that professional training increased the adoption of inbound practices and innovations.

Regarding innovation management, the findings indicate that larger firms have an advantage as they have the resources to nurse the novel idea. Small firms may need to take a risk and "open up" supplying more detailed information on their idea or enlist the aid of an intermediary with a professional affiliation. Entrepreneurs need to unpack the barriers and react strategically rather than emotionally to gain entrance to the field. An alignment of new and existing practices would lead to a fruitful collaboration.

A major limitation of this study is that we present only the view of the entrepreneurs and not the views of external professionals. As stated, we approached the study from the field of innovation. We refer specifically to new product management literature together with practice theory to highlight countering forces to new practices. We suggest that future research explore entrepreneurial practices and professional practices in juxtaposition, thus better highlighting the practices involved for innovation acceptance. Another direction for further research is investigate the identified barriers in a larger quantitative study to identify whether and to what degree professional opposition varies in relation to different industries and professional communities.

Acknowledgment. This research was funded by the Research Council of Norway and the County of Rogaland, through the VRI programme.

6 References

Alvesson, M., & Kärreman, D. (2007). Constructing mystery: Empirical matters in theory development. *Academy of Management Review, 32*(4), 1265-1281.

Beers, C., & Zand, F. (2014). R&D Cooperation, Partner Diversity, and Innovation

Performance: An Empirical Analysis. *Journal of Product Innovation Management, 31*(2), 292-312. doi:10.1111/jpim.12096

Berglann, H., Moen, E., Røed, K., & Skogstrøm, J. F. (2009). *Entrepreneurship: Origins and returns*. Retrieved from Oslo:

Brante, T. (2011). Professions as Science-Based Occupations. *Professions & Professionalism, 1*(1), 4-20.

Burcharth, A. L. d. A., Knudsen, M. P., & Søndergaard, H. A. (2014). Neither invented nor shared here: The impact and management of attitudes for the adoption of open innovation practices. *Technovation, 34*(3), 149-161. doi:10.1016/j.technovation.2013.11.007

De Clercq, D., & Voronov, M. (2009). Toward a Practice Perspective of Entrepreneurship: Entrepreneurial Legitimacy as Habitus. *International Small Business Journal, 27*(4), 395-419. doi:10.1177/0266242609334971

Doern, R. (2009). Investigating barriers to SME growth and development in transition environments: A critique and suggestions for developing the methodology. *International Small Business Journal, 27*(3), 275-305.

Doern, R., & Goss, D. (2013). From barriers to barring: Why emotion matters for entrepreneurial development. *International Small Business Journal, 31*(5), 496-519.

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology, 70*(113).

Freel, M. S. (2000). Barriers to Product Innovation in Small Manufacturing Firms. *International Small Business Journal, 18*(2), 60-80.

Gherardi, S. (2001). From organizational learning to practice-based knowing. *Human Relations, 54*(1), 131-139.

Gherardi, S., & Landri, P. (2014). "I sign, therefore I am" (Un)stable traces of professional practices. *Professions & Professionalism, 4*(2), 1-11.

Gourlay, S. (2006). Towards conceptual clarity for 'tacit knowledge': A review of empirical studies *Knowledge Management Research & Practice, 4*(1), 60-69.

Hall, J., Bachor, V., & Matos, S. (2014). The impact of stakeholder heterogeneity on risk perceptions in technological innovation. *Technovation, 34*(8), 410-419.

Hawkins, M. A., & Rezazade, M. (2012). Knowledge boundary spanning process: synthesizing four spanning mechanism. *Management Decision, 50*(10), 1800-1815.

Huang, Y.-A., Chung, H.-J., & Lin, C. (2009). R&D sourcing strategies: Determinants and consequences. *Technovation, 29*(3), 155-169. doi:http://dx.doi.org/10.1016/j.technovation.2008.08.002

Johannisson, B. (2011). Towards a practice theory of entrepreneuring. *Small Business Economics, 36*(2), 135-150. doi:10.1007/s11187-009-9212-8

Johannisson, B. (2012). Tracking the everyday practices of societal entrepreneuring. In K. Berglund, B. Johannisson, & B. Schwartz (Eds.), *Societal entrepreneurship: positioning, penetrating, promoting* (pp. 60-88). Cheltenham, UK: Edward Elgar Publishing, Inc.

Johannisson, B. (2014). The practice approach and interactive research in entrepreneurship and small-scale venturing. In A. Carsrud & M. Brännback (Eds.), *Handbook of Research Methods and Applications in Entrepreneurship and Small Business* (pp. 228-258). Cheltenham, UK: Edward Elgar Publishing, Inc.

Kahn, K. B., Barczak, G., & Moss, R. (2006). Dialogue on best practices in new product development perspective: Establishing an NPD best practices framework. *Journal of Product Innovation Management, 23*, 106-116.

Kahn, K. B., Barczak, G., Nicholas, J., Ledwith, A., & Perks, H. (2012). An Examination of New Product Development Best Practice. *Journal of Product Innovation Management, 29*(2), 180-192. doi:10.1111/j.1540-5885.2011.00888.x

Kaufmann, A., & Tödtling, F. (2002). How effective is innovation support for SMEs? An analysis of the region of Upper Austria. *Technovation, 22*(3), 147-159. doi:http://dx.doi.org/10.1016/S0166-4972(00)00081-X

Kerosuo, H., Kajamaa, A., & Engeström, Y. (2010). Promoting innovation and learning through Change Laboratory: An example from Finnish Health care. *Central European Journal of Public Policy, Special Issue on Knowledge Governance, 4*(1).

Lin, B.-W., & Wu, C.-H. (2010). How does knowledge depth moderate the performance of internal and external knowledge sourcing strategies? *Technovation, 30*(11–12), 582-589. doi:http://dx.doi.org/10.1016/j.technovation.2010.07.001

Mieg, H. A., de Sombre, S., & Näf, M. A. (2013). How Formality Works: The Case of Environmental Professionals. *2013, 3*(1). doi:10.7577/pp.564

Munro, G. D. (2010). The Scientific Impotence Excuse: Discounting Belief-Threatening Scientific Abstracts. *Journal of Applied Social Psychology, 40*(3), 579-600. doi:10.1111/j.1559-1816.2010.00588.x

Musteen, M., & Ahsan, M. (2013). Beyond Cost: The Role of Intellectual Capital in Offshoring and Innovation in Young Firms. *Entrepreneurship: Theory & Practice, 37*(2), 421-434. doi:10.1111/j.1540-6520.2011.00477.x

Narula, R. (2004). R&D collaboration by SMEs: new opportunities and limitations in the face of globalisation. *Technovation, 24*(2), 153-161. doi:http://dx.doi.org/10.1016/S0166-4972(02)00045-7

Parry, S. (2010). Smalltalk: Rhetoric of control as a barrier to growth in artisan micro-firms. *International Small Business Journal, 28*(4), 378-397.

Pfeffer, J., & Sutton, R. I. (2006). Evidence-Based Management (Vol. 84, pp. 184-184): Harvard Business School Publication Corp.

Saks, M. (2012). Defining a Profession: The Role of Knowledge and Expertise. *Professions & Professionalism, 2*(1), 1-10.

Sarasvathy, S. D. (2001). *What Makes Entrepreneurs Entrepreneurial?* Darden Business Publishing. University of Virginia.

Sarasvathy, S. D. (2009). *Effectuation: Elements of Entrepreneurial Expertise*. Northampton, MA: Edward Elgar Publishing.

Schatzki, T. (1997). Practices and actions: A Wittgensteinian critique of Bourdieu and

Giddens *Philosophy of the Social Sciences, 27*(3), 283-308.

Schatzki, T. (2002). *The site of the social: A philosophical account of the constitution of social life and change*. Pennsylvania: The Pennsylvania State University Press.

Schatzki, T. (2005). Peripheral vision: The sites of organizations. *Organization Studies, 26*(3), 465-484. doi:10.1177/0170840605050876

Schatzki, T. (2006). On organizations as they happen. *Organization Studies, 27*(12), 1863-1873. doi:10.1177/0170840606071942

Schatzki, T. (2010). *The timespace of human activity: On performance, society, and history as indeterminate teleological events*. Lanham, MD.: Lexington Books.

Schatzki, T. (2012). A primer on practices: Theory and research. In J. Higgs, R. Barnett, S. Billett, M. Hutchings, & F. Trede (Eds.), *Practice-based education: Perspectives and strategies* (pp. 13-26). Rotterdam: Sense Publishers.

Schatzki, T. (2013). The Edge of Change: On the Emergence, Persistence, and dissolution of Practices. In E. Shove & N. Spurling (Eds.), *Sustainable Practice: social theory and climate change* (pp. 31-46). New York: Routledge.

Schatzki, T. (2016a). Keeping Track of Large Social Phenomena. *Geographische Zeitschrift, 104*(1), 4-24.

Schatzki, T. (2016b). Praxistheorie als flache Ontologie. In H. Schäfer (Ed.), *Praxistheorie. Ein soziologisches Forschungsprogramm* (pp. 29-44). Bielefeld: Transcript Verlag.

Schatzki, T., Knorr Cetina, K. D., & von Savigny, E. (Eds.). (2001). *The practice turn in contemporary theory*. London: Routledge.

Slappendel, C. (1996). Perspectives on innovation in organization *Organization Studies, 17*(1).

Steyaert, C., & Landström, H. (2011). Enacting entrepreneurship research in a pioneering, provocative and participative way: on the work of Bengt Johannisson. *Small Business Economics, 36*(2), 123-134. doi:10.1007/s11187-009-9213-7

Stringfellow, L., Shaw, E., & Maclean, M. (2014). Apostasy versus legitimacy: Relational dynamics and routes to resource acquisition in entrepreneurial ventures. *International Small Business Journal, 32*(5), 571-592. doi:10.1177/0266242612471693

Teirlinck, P., & Spithoven, A. (2013). Research collaboration and R&D outsourcing: Different R&D personnel requirements in SMEs. *Technovation, 33*(4–5), 142-153. doi:http://dx.doi.org/10.1016/j.technovation.2012.11.005

Thorpe, R., Gold, J., Holt, R., & Clarke, J. (2006). Immaturity: The Constraining of Entrepreneurship. *International Small Business Journal, 24*(3), 232-250. doi:10.1177/0266242606063431

van de Vrande, V., de Jong, J. P. J., Vanhaverbeke, W., & de Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. *Technovation, 29*(6–7), 423-437. doi:10.1016/j.technovation.2008.10.001