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Evidence of Lead Users in Past Innovations

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Abstract

Innovations have drawn much attention due to their economic and social importance. Many models and theories have been developed to understand how innovations emerge, are developed and become popular. To ensure innovation's commercial success and a good market position, understanding of users' needs and expectations is obligatory. To increase such understanding, this paper examines the lead user method in innovation development processes. This examination is based on a literature review and a list of top 30 innovations from the last 30 years. The overall objective is to analyse the most renowned innovations and to identify the innovations that show evidence of a lead user like approach. Lead user is here understood as a person or group who has a need earlier than the mass market and has come up with a solution for it. The analysis was performed by exploring the development of the selected 30 innovations. We find that 37% of the 30 innovations show evidence of a lead user in the beginning stages of the innovation process. We also compared these lead user innovations to the other innovations on the same list and found that the lead user innovations were more likely radical innovations. The most common application domains for the lead user innovations were military and medical.

Keywords: Product development, innovation, lead user

1 Introduction

Today competition is more intense than ever due to the global market and the new needs arising from it. Obtaining a competitive edge depends on multiple factors and innovativeness is one of the most essential elements in gaining competitive advantage. (Dereli, 2015) Due to their economic and social importance, innovations have drawn much attention. In science, many models and theories have been developed to understand how innovations emerge, are developed and become popular. (Rilla et al., 2007)

Innovation's commercial success is influenced by many factors. However, the most successful innovations have higher rates of innovative architecture and enhanced user interactions (Saunders, Seepersad & Hölttä-Otto, 2011) and to ensure innovation's commercial success and a good market position, understanding of users' needs and expectations is virtually obligatory

(Rothwell et al., 1974). To increase such understanding, this paper examines the lead user method in innovation development processes. In this paper, a lead user is understood as a person or a group that has an enormous need that does not yet exist in the marketplace but will become common in the future. Lead users also benefit enormously from the solution to their need.

This examination is based on a literature review and a global listing of top 30 innovations from the last 30 years. The overall objective is to analyse the most renowned innovations and to identify the innovations that show evidence of a lead user like approach.

2 Background

Innovations have an indisputable significance to both economic growth (Magalhãesa & Alfonsoc, 2017) and single companies' competitiveness (Rilla et al., 2007). Due to their importance, inventions and innovations have gained much academic attention in the recent years, resulting in many models and theories developed to understand their emergence and development. (Rilla et al., 2007)

Innovation is an idea, object or a method, which is perceived as new to its users. (Rogers, 1983; Siltala, 2009) It provides value to its user and its objective age does not matter. Innovations differ from inventions due to the value they provide and their diffusion. Invention transforms into an innovation when it is being produced and has been diffused to the markets. (Garcia & Calantone, 2002)

Innovations can be categorized by their newness: they can be brand new in the world, in an industry or merely in one company. (Apilo & Taskinen, 2006) Based on their newness, they can also be categorized to be incremental, architectural, modular or radical. Incremental and architectural innovations extend earlier designs, whereas modular and radical innovations change the core design concepts of a new technology. (Henderson & Clark. 1990) Briefly, modular and radical innovations are entirely new, where incremental and architectural innovations are only improvements to old, existing innovations.

Product development is a multiphase process, the goal of which is to develop a new or improved product, or innovation. Its goal can also be altering the purpose of use of a product or a system. (Jokinen, 2010) However, innovations are not always the result of a systematic development effort, but their development can be influenced by individual events, history-specific problems or the opportunities provided by new technology. (Taalbi, 2017) Product development is tightly connected to other parts of the production process and marketing. (Jokinen, 2010)

In a successful product development, it is important to understand user needs (Rothwell et al., 1974) and the most successful innovations have significantly enhanced user interactions compared to less successful innovations (Saunders et al., 2011). In some industries, new innovations do not differ much from the old products, in which case marketing research can rely on typical users. However, especially in high-technology industries, the development is so rapid that ordinary users' needs are typically already outdated when the new product is developed to the market. In this case, market research can harness lead users, because the needs they face will become common in the marketplace in the future. (von Hippel, 1986) This lead user method has been proved to be remarkably efficient especially among big consumer and industry product manufacturers' product development (Herstatt & von Hippel, 1992; Eisenberg, 2011; Judge, Hölttä-Otto, Winter, 2015). Consequently, methods to find and use lead users have been developed. (Schuhmacher & Kuester, 2012; Hölttä-Otto & Raviselvam, 2016)

Because lead users can be of such significant value to high-technology industries' product development, we examine if lead users might have been involved also unintentionally in past innovations. More specifically we examine how often lead users have had an influence in the beginning stages of product development in the most renowned innovations.

3 Empirical study

For data about the most renowned innovations we searched for a list that would have over 25 modern and global innovations listed. We found multiple lists, but most of them were either restricted in scope and had less than 15 innovations or all the innovations were invented within a certain year or then all the innovations were commercial products. For this paper, we use the Nightly Business Report's and Knowledge@Wharton's listing of the top 30 innovations from the last 30 years. The final choice was affected by the scale of the listing, globality of the innovations on the listing, modernity of the innovations and the number of participants in the questionnaire for the listing (n>1,000).

3.1 Criteria for analysis

In this examination, we examine lead user innovations and adopt the essential criteria defined in prior literature for lead users: 1) Lead users have a certain enormous need, 2) This need will become common in the market place only later and 3) Lead users greatly benefit from the solution to that certain need. (von Hippel, 1986) The definition of lead users essentially includes that the need they face will become common in the marketplace in the future. In this study, all the innovations are in mass use currently so they all fulfil this criterion. It is worth noting that there were lead users available for some innovations, but if those lead users were not harnessed into the development process of the final innovation, those innovations cannot be perceived to show evidence of a lead user like approach.

For the developers to be categorized as lead users, the need they faced must had been so enormous that they had to develop the solution to that need by themselves. This is the essential difference between lead users and first adopters. In this paper, we determine innovation to have had a lead user like approach also when the lead user himself did not accomplish the actual product development but triggered the product development of the innovation.

When defining the product development process, it is important to investigate if the development of the innovation has been a natural continuum to the specific technology's development or whether there has been a significant need that no one else yet has, causing the development to begin and if the developer himself benefited greatly from the solution to that need. Many of the innovations in the listing have a long development history, and depending on the definition and framing, the innovation can be seen to have been developed at different times. For this analysis, the time of the development of an innovation is the moment when the innovation was transformed from an idea into something concrete and when the innovation responded to the same need it responds to today.

We categorize innovations simply into lead user innovations and non-lead user innovations. We further categorize lead user innovations strictly to incremental and radical innovations by their newness; how much the innovation's core concept was altered or kept the same. This analysis does not exclude other types of findings. We acknowledge, but do not treat in more detail, that a lead user innovation may also show signs of other categories, such as demand- or market-pull and science- or technology-push (Lubik et al., 2012).

3.2 Analysis & Results

After examining the development of the 30 innovations, we categorized all the innovations in terms of their newness and whether they, in fact showed evidence of a lead user like approach or not. In some cases, the innovation was developed, but it did not offer a solution to a certain need and was not put into use until later. In these cases, the innovation did not show evidence of lead user like approach since it did not solve a great need as soon as it was developed. Even if these innovations were later adopted by only few users and later by masses, this user group would be categorized as early adopters rather than lead users.

The first column in Table 1 lists all the top 30 innovations that were on our sample. The second column indicates a simple yes or no depending whether the innovation showed evidence of a lead user like approach in its development. Finally, the last column shows if the innovation was new, radical or incremental. This last categorization is made only to the innovations that show evidence of a lead user like approach, since they are at the core of this analysis.

Table 1. The most renowned innovations and their categorization

Innovation	Lead user?	Innovation type
Internet	Yes	Radical
Personal computer (PC)	No	
Mobile phone	No	
E-mail	Yes	Radical
DNA testing and sequencing	No	
Magnetic resonance imaging (MRI)	No	
Microprocessor	No	
Fibre optics	No	
Office software	Yes	Radical
Non-invasive laser/robotic surgery (laparoscopy)	Yes	Radical
Open source software	Yes	Incremental
Light emitting diodes (LED)	No	
Liquid crystal display (LCD)	No	
Global positioning system (GPS)	Yes	Incremental
Online shopping	No	
Media file compression	No	
Microfinance	No	
Photovoltaic solar energy	No	
Large scale wind turbine	No	
Social networking via the internet	No	
Graphic user interface (GUI)	Yes	Radical
Digital photography	No	
RFID and applications	Yes	Radical
Genetically modified plants	No	
Bio fuel	No	
Barcode and scanner	Yes	Radical
Automatic teller machine (ATM)	Yes	Incremental
Stents	Yes	Radical
SRAM memory	No	
Anti-retroviral treatment for AIDS	No	

Next, we will go through all the innovations that showed evidence of a lead user like approach and explain why they did:

1) Internet. After USSR had launched its Sputnik-satellite fear started to grow in the USA that USSR could destroy the US telecommunications links from space. Hence, the USA had a need to develop a communication system that would not be centrally operated, since centralized communication systems could easily be destroyed with a single nuclear strike. (Metz, 2012) USA government established Advanced Research Projects Agency (ARPA) to create a solution. ARPA later successfully created ARPANET (Leiner et al., 1997) which is based on a distributed system idea created by the US army think tank RAND Corporation. In the case of the internet, the US government was the lead user that had a great need before it became common and greatly benefited from the solution.
2) E-mail. Central computers were widely used in Massachusetts Institute of Technology (MIT) where they had hundreds of users. These users were connected to the main frame computer that did all the calculations, from their own work posts. These users had a need to leave messages to the next users of the main frame computer, which is why they created the MAILBOX software that allowed users to leave messages to other computers using the same mainframe computer. The development of PCs and especially the growing usage of ARPANET made that need more common and later this technology evolved to e-mail. (Peter, 2004) MIT's main frame computer users were the lead users of E-mail since they had the same need before the masses and they greatly benefited from the solution.
3) Office software. Office software is not merely a one innovation, and in this paper, we analysed two of the most renowned innovations in office software: word processing and spreadsheets. The need for word processing goes back centuries and popularisation of typewriters made this need common. (Kunde, 1998) Word processing technology developed with this already common need, which explains why it cannot be said to have had evidence of a lead user like approach. On spreadsheets, however, Dan Bricklin, a student at Harvard School of Business, had an assignment that would had been very laborious with the technology available at that time. He started to develop a software where the chart would be visible while working on it and could be edited. (Power, 2004) Office software can be said to have evidence of a lead user like approach since the need Bricklin faced was not common at the time but became common later and because of the benefit he got from the solution.
4) Non-invasive laser/robotic surgery (laparoscopy). Especially in urologic and gynaecologic procedures, the doctors had a need to make the procedures less invasive. Phillip Bozzini figured out a way to make these procedures less invasive and cause less pain to the patient. This laparoscopy was first adopted in the fields of urology and gynaecology, but later it diffused to other sectors of medical procedures. Even though laparoscopy had already made these procedures less invasive, there was still a need to make them even more so. Laser and robotic surgeries were invented later for that need. (Hatzinger et al., 2006) In this case, laparoscopy shows evidence of a lead user like approach since the way laparoscopy was developed for a great need that was not yet common, and the developers benefited greatly from the solution.
5) Open source software. In 1955, IBM created IBM User Group Share to exchange codes and to solve IBM's need to better understand their IBM OS operating system. In IBM User Group Share, the users could exchange codes with each other and the source code for the operating system was available for all the users. This type of source code -sharing is the foundation to all open source software and services. IBM had a great need that

they solved themselves. Later this need has become more common and open source software are common in all fields of software industry. (Zuo, Qiu & Markaida, 2013)

6) Global positioning system (GPS). In GPS we will only examine the Global Positioning System and not just satellite positioning or its individual parts. Before GPS was developed, there were already satellite positioning systems developed, but they were not very practical or accurate (Poole). The US army had a need to locate their submarines located in the seas much faster and more accurately. They started the development process and combined three existing technologies into one, creating the GPS. This need for faster and more accurate positioning system has become more common later, first for civilian air traffic and later to everyone. (LaMarca & de Lara, 2008)
7) Graphic user interface (GUI). Graphic user interface had been envisioned before but nothing commercial had been developed yet. In 1970 photocopy company Xerox formed Palo Alto Research Centre (PARC) where one of the first products developed was a laser printer. However, researchers quickly discovered that the current technology did not allow them to use the printer, but they needed a more graphical way of producing documents with a computer. To solve this need, they developed the first graphic user interface. (Reimer, 2005) Later this need for GUI has become more common and it has enabled computers to become common.
8) RFID and applications. In the Second World War Germans, Japanese, Americans and British were using radars to detect incoming aircraft but radar alone could not identify if the aircraft was ally of foe. To solve this need, the Germans invented the first passive RFID system when they discovered that the radio signal the aircraft reflects changed when the aircraft waved its wings. (Violino, 2005) Later this need for identification has become common and today RFID is used for road tolls, in medicine, banking and even retail.
9) Barcodes and scanners. A local grocery store chain owner had a need for automatic product identification at the checkouts and he asked Drexel Institute of Technology to create a solution for it. Students Silver and Woodland started working on the problem and developed patterns that were used to individualize products with scanners. Later standards were made for these patterns and today they are in institutionalised mass use. (Bellis, 2017) The store chain owner had a great need that was not common yet at that time. Even though the store chain owner did not come up with the solution to his problem by himself, he was the main trigger behind barcode and scanner development and hence it can be said that they did have evidence of a lead user like approach.
10) Automatic teller machine (ATM). In this study, Automatic Teller Machines does not refer to cash dispensers, but machines that allow users to also check their account information. The development of ATMs began when Swedish bankers wanted to respond to rising labour costs. They had a need to offer basic banking services with less labour and hence they developed ATMs. (Bàtiz-Lazo, 2015) Later the rise of labour costs has spread around the globe and the need Swedish bankers had, has become common.
11) Stents. The treatment of coronary diseases had already evolved significantly, but their surgeries often caused major complications in the coronary artery, which could prove to be fatal to the patient. Ulrich Sigwart et al. solved that problem and developed stents that support the arteries during the surgery, reducing complications substantially. (Sigwart, Puel, Mirkovitch, Joffre & Kappenberger, 1987) The need can be said to have been great since it involved saving human lives. Today stents are applied in medicine for all types of artery surgeries, not only for coronary-arteries.

In our sample, we found a total of 11 innovations that show evidence of a lead user like approach: 1) Internet, 2) E-mail, 3) Office software, 4) Non-invasive laser and robotic surgery (laparoscopy), 5) Open source software, 6) GPS, 7) GUI, 8) RFID and applications, 9) Barcodes and scanners, 10) ATMs, 11) Stents. From the 30 innovations in our listing, a total of 36.7% showed evidence of a lead user like approach.

Most of the innovations that did not show evidence of a lead user like approach did not have a significant need behind the product development process. For example, LED was invented by Henry Round when he was experimenting with crystal of silicone carbide and cat's whisker detector and created the first light emitting diode. (Bausch, 2011) This development process did not have any need behind it and hence, cannot be said to have had a lead user like approach.

From these 11 innovations, that show evidence of a lead user like approach, none had been intentionally developed with the use of lead user method. However, since the need they had faced was so great, they aimed to either solve the problem themselves or sought outside help for solving it.

Two major developers emerge from the findings: military and medical organizations. The needs these groups encounter seem to have shared features as they are compulsive, urgent and acute, and often the solution to their needs helps prevent human casualties or lessen suffering.

From the 11 innovations that show evidence of a lead user like approach, eight are currently available for the markets and can be used by anyone. Three of these innovations, non-invasive laser/robotic surgery, stents, and barcodes and scanners are in institutional use. Barcodes and scanners are currently mostly in institutional use, but their usage is becoming more common due to self-checkouts, price-check devices and phone applications. Non-invasive laser/robotic surgery and stents, however, are medical innovations and it is unlikely their usage will become more common in the future because of their expert purpose of use.

In internet and communication technology (ICT), innovations leaning on the lead user method were significantly more common. In the present sample, there are 15 ICT innovations and as much as nine (60%) showed evidence of a lead user like approach.

Understanding of users' needs and expectations is virtually obligatory for the development of new innovations and the advantages in technology are extremely rapid in high-technology industries and market research can no longer succeed with ordinary customers. Hence, lead users can be a remarkable asset in high-technology industries' market research. ICT innovations can be categorized as high-technology innovations, hence it was expected that they would show more evidence of a lead user like approach.

4 Discussion

In this paper, we examined if lead users might have been unintentionally involved in past innovations. We analysed 30 of the most renowned innovations and by using existing lead user criteria, we analysed which of these innovations' development took a lead user like approach. We found that 11 of the 30 innovations (36.7%) showed evidence of a lead user like approach in the beginning stages of the innovation process. These innovations are 1) Internet, 2) E-mail, 3) Office software, 4) Non-invasive laser and robotic surgery (laparoscopy), 5) Open source software, 6) GPS, 7) GUI, 8) RFID and applications, 9) Barcodes and scanners, 10) ATMs, 11) Stents.

Two major innovator groups, that had harnessed lead users, emerged from the findings: military and medical organizations. Innovations related to information and communications technology (ICT) were also more likely to show evidence of a lead user like approach. The greatest difference between lead user innovations and others in our sample was the magnitude of the need behind the product development.

Another difference between these two groups is the newness of the innovations. Lead user innovations were more likely to be radical, whereas the other innovations were more likely to be incremental innovations. None of the innovations on our sample were so called new innovations because of the criteria we used for the listing that required all the innovations to be groundbreaking.

Our study indicates that in some industries, a certain compelling need may be fundamentally linked to the innovation process. Based on our analysis, we see possibilities for further study on the closer analysis of the two criteria identified in this paper:

1) The need is acute and compelling
2) The need is linked to saving human lives.

Discussion of compellingness leads us deeper into the social discussion on how to accelerate the innovation process with better resourcing. There have been no conclusive findings regarding whether individuals or organisations innovate better when forced to create a solution rather than when receiving plenty of resources. This paper indicates that when the reasons behind the innovation process are not compelling, resourcing can be the critical factor in successful innovating.

References

A brief history of email. Retrieved from http://www.vicomsoft.com/knowledge/reference/email.history.html

Aldrich, M. (2011). *History of online shopping*. Retrieved from http://www.aldricharchive.com/shopping_history.html

Apilo, T. & Taskinen, T. (2006). *VTT tiedotteita. Innovaatioiden johtaminen*. Retrieved from VTT database.

Bàtiz-Lazo, B. (2015). *A brief history of the ATM*. Retrieved from https://www.theatlantic.com/technology/archive/2015/03/a-brief-history-of-the-atm/388547/

Bausch, J. (2011). *The long history of light-emitting diodes*. Retrieved from https://www.electronicproducts.com/Optoelectronics/LEDs/The_long_history_of_light-emitting_diodes.aspx

Bellis, M. (2017). *Bar codes*. Retrieved from https://www.thoughtco.com/bar-codes-history-1991329

Bellis, M. (2017). *History: Photovoltaics timeline*. Retrieved from https://www.thoughtco.com/photovoltaics-timeline-1992481

Bellis, M. (2017). *How fiber optics was invented*. Retrieved from https://www.thoughtco.com/birth-of-fiber-optics-4091837

Bellis, M. (2017*). Liquid crystal display – LCD*. Retrieved from https://www.thoughtco.com/liquid-crystal-display-history-lcd-1992078

Bellis, M. (2017). *Magnetic resonance imaging MRI*. Retrieved from

https://www.thoughtco.com/magnetic-resonance-imaging-mri-1992133
Bellis, M. (2017). *The history of MP3*. Retrieved from https://www.thoughtco.com/history-of-mp4-1992132
Brief laparoscopic history. Retrieved from http://www.laparoscopicexperts.com/introduction/
Castellano, J. A. (2005). *Liquid gold: The story of liquid crystal displays and the creation of an industry*. Singapore: Mainland Press.
Dereli, D. D. (2015). Innovation management in global competition and competitive advantage. *Procedia – Social and Behavioral Sciences, 195*(July), 1365-1370.
Driscoll, K. (2016). *Social media's dial-up ancestor: The bulletin board system* Retrieved from https://spectrum.ieee.org/tech-history/cyberspace/social-medias-dialup-ancestor-the-bulletin-board-system
Eisenberg, I. (2011). Lead-user research for breakthrough innovation. *Research-Technology Management*, 54(1), 50-58.
Editorial team. (2016). *The history of online shopping – From the 1960's to the 1990's*. Retrieved from https://1stwebdesigner.com/history-of-online-shopping/
Garcia, R. & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management, 19*(2), 110-132.
Hatzinger, M., Kwon, S. T., Langbein, S., Kamp, S., Axel Häcker, A. & Alken, P. (2006). Hans Christian Jacobaeus: Inventor of human laparoscopy and thoracoscopy. *Journal of Endourology, 20*(11), 848-850.
Heather, J. M. & Chain, B. (2016). The sequence of sequencers: The history of sequencing DNA. *Genomics, 107*(1), 1-8.
Henderson, R. & Clark, K. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly, 35*(1), 9-30.
Herstatt, C. & von Hippel, E. (1992). From experience: Developing new product concepts via the lead user method: a case study in a "low-tech" field. *The Journal of Product Innovation Management, 9*(3), 213-221.
History.com Staff. (2011). *Invention of the PC*. Retrieved from http://www.history.com/topics/inventions/invention-of-the-pc
History of microfinance. Retrieved from http://www.microfinanceinfo.com/history-of-microfinance/
History of photovoltaic (PV) solar energy. Retrieved from http://ariseenergy.com/training-education/history-of-pv-solar-energy
Hölttä-Otto, K. & Raviselvam, S. (2016). Guidelines for Finding Lead User Like Behavior for Latent Need Discovery. DS 85-2: *Proceedings of NordDesign 2016*, Volume 2, Trondheim, Norway, 10th-12th August 2016.
Jokinen, T. (2010). *Tuotekehitys*. Retrieved from http://lib.tkk.fi/Reports/2010/isbn9789526033204.pdf
Judge, B. M., Hölttä-Otto, K., & Winter, A. G. (2015). Developing world users as lead users: a case study in engineering reverse innovation. *Journal of Mechanical Design*, 137(7), 071406.
Juva, A. & Aukia, J-P. (2011). *Tekesin katsaus 285. Uusiutuvan dieselin kehityspolku.* Retrieved from Tekes database.
Kaldellis, J. K. & Zafirakis, D. (2011). The wind energy (r)evolution: A short review of a long history. *Renewable Energy, 36*(7), 1887-1901.
Knowledge@Wharton. (2009). *A world transformed: What are the top 30 innovations of the last 30 years?*. Retrieved from http://knowledge.wharton.upenn.edu/article/a-

world-transformed-what-are-the-top-30-innovations-of-the-last-30-years/
Kovarik, B. (2013). Biofuel crops: production, physiology and genetics. B.P. Singh (Ed), *Biofuels in history* (pp. 1-22). Oxfordshire, United Kingdom: CABI
Kunde, B. (1998). *A brief history of word processing (through 1986)*. Retrieved from https://web.stanford.edu/~bkunde/fb-press/articles/wdprhist.html#B
LaMarca, A. & de Lara, E. (2008). *Location systems. An Introduction to the technology behind location awareness*. Morgan & Claypool Publishers.
Leiner, B.M., Cerf, V.G., Clark, D.D., Kahn, R.E., Kleinrock, L., Lynch, D.C., Postel, J., Roberts, L.G. & Wolff, S. (1997). *Internet history timeline*. Retrieved from https://www.internethalloffame.org//internet-history/timeline
Lubik, S., Lim, S., Platts, K. & Minshall, T. (2012). Market-pull and technology-push in manufacturing start-ups in emerging industries. *Journal of Manufacturing Technology Management, 24*(1), 10-27.
Magalhãesa, M. & Afonsoc, O. (2017). A multi-sector growth model with technology diffusion and networks. *Research Policy, 46*(7), 1340-1359.
Metz, C. (2012). *Paul Baran, the link between nuclear war and the internet*. Retrieved from http://www.wired.co.uk/article/h-bomb-and-the-internet.
Nixon, N. (2008). *Timeline: The history of wind power*. Retrieved from https://www.theguardian.com/environment/2008/oct/17/wind-power-renewable-energy
Perkins, A. (2008). *A short history of microfinance*. Retrieved from https://www.theguardian.com/katine/2008/jun/03/livelihoods.projectgoals1
Peter, I. (2004). *The history of email*. Retrieved from http://www.nethistory.info/History%20of%20the%20Internet/email.html
Poole, I. *GPS history, dates & timeline*. Retrieved from http://www.radio-electronics.com/info/satellite/gps/history-dates.php
Power, D.J (2004). *A brief history of spreadsheets*. Retrieved from https://web.archive.org/web/20170831130538/http://www.dssresources.com/history/sshistory.html
Rangel, G. (2015). *From corgis to corn: A brief look at the long history of GMO technology*. Retrieved from http://sitn.hms.harvard.edu/flash/2015/from-corgis-to-corn-a-brief-look-at-the-long-history-of-gmo-technology/
Reimer, J. (2005). *A history of the GUI*. Retrieved from https://arstechnica.com/features/2005/05/gui
Rilla, N., Saarinen, J., Kivisaari, S., Konttinen, J., Mäkinen, I., Oksanen, J., Pesonen, P. & Rantakari A. (2007). *Teknologiakatsaus 197. Tutkimusmatka innovaatioihin*. Retrieved from Tekes database.
Rogers, E. M. *Diffusion of innovations*. (1983). New York, New York, USA: The Free Press.
Rosenfeld, S.A. (2003). *The genesis of a technological revolution*. Retrieved from https://history.nih.gov/exhibits/linc/docs/page_08.html
Rothwell, R., Freeman, C., Horsley, A, Jervis, V. T. P., Robertson, A. B. & Townsend, J. (1974). SAPPHO updated – project SAPPHO phase II. *Research Policy, 3*(3), 258-291.
Saunders, M. N., Seepersad, C.C. & Hölttä-Otto, K. (2011). The characteristics of innovative, mechanical products. *Journal of Mechanical Design, 133*(2):021009-021009-9.
Schuhmacher, M. C., & Kuester, S. (2012). Identification of lead user characteristics driving the quality of service innovation ideas. *Creativity and Innovation Management*, 21(4), 427-442.
Shah, S. (2016). *The history of social networking*. Retrieved from

https://www.digitaltrends.com/features/the-history-of-social-networking/
Shirriff, K. (2016). *The surprising story of the first microprocessors*. Retrieved from https://spectrum.ieee.org/tech-history/silicon-revolution/the-surprising-story-of-the-first-microprocessors
Sigwart, U., Puel, J., Mirkovitch, V., Joffre, F. & Kappenberger, L. (1987). Intravascular stents to prevent occlusion and restenosis after transluminal angioplasty. *The New England Journal of Medicine, 316*(12), 701-706.
Siltala, R., Suomala, J., Taatila, V., Keskinen S., Hakala J. & Luoto A. (2009). *Laurea-ammattikorkeakoulun julkaisusarja A 68. Innovaatioiden lähteillä.* Retrieved from Laurea-ammattikorkeakoulu database.
SRAM memory. Retrieved from http://www.chipsetc.com/sram-memory.html.
Storm, C. (2015). *In just one hour, two Bell Labs scientists had a breakthrough that won the Nobel prize – and changed photography forever*. Retrieved from http://www.businessinsider.com/digital-photography-revolution-2015-4?r=US&IR=T&IR=T
Taalbi, J. (2017). What drives innovation? Evidence from economic history. *Research Policy, 46*(8), 1437–1453.
Tretkoff, E. (2006). This month in physics history. *APS News, 15*(7). 2.
Vella, S., Schwartländer, B., Sow, S.P., Eholie, S.P. & Murphy, R.L. (2012). The history of antiretroviral therapy and of its implementations in resource-limited areas of the world. *AIDS 26*(10), 1231-1241.
Verma, S. *Invention story of cell phones*. Retrieved from https://www.engineersgarage.com/invention-stories/mobile-phone-history
Violino, B. (2005). *The history of RFID technology*. Retrieved from http://www.rfidjournal.com/articles/view?1338
von Hippel, E. (1986). Lead users: A source of novel product concepts. *Management Science, 32*(7), 791-805.
Wolfram, S. (2002). *A new kind of science*. Wolfram Media, Inc. Retrieved from https://www.wolframscience.com/nks/
Woolsey, G. L. (2012). *GMO timeline: A history of genetically modified foods*. Retrieved from http://www.gmoinside.org/gmo-timeline-a-history-genetically-modified-foods/
Zuo, W., Qiu, D. & Markaida, A. (2013). *Open source software's history, evolution and future development*. Retrieved from https://wiki.oulu.fi/display/ossd/Seminars+2013