Article

JIM
ISSN: 2183-0606

Vol. 11, 4 (2023)
p. 143-169
AM: Dec/2023
SM: Aug/2019

Will Machines Innovate for and with Us - What Kind of Strategic Themes Could Belong to Innovation Automation?

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Abstract

The Internet economy and computer-aided innovation enable improvements in the quality and quantity of outcomes of innovation processes. Traditional "research pipes" are often too slow to fit with contemporary business logic. In this paper, we focus on the intersection of innovation and automation and the potential they create together. Innovation automation represents a next generation of automation that has structural implications. Automation in the innovation context is about maintaining the richness of creative innovation processes while also absorbing a greater amount of data, information, and knowledge inputs and producing more holistic outputs that meet customer needs better and are faster on the market. The paper builds a novel academic "playground" for the research on innovation automation as *the efficient and effective use of co-creative intelligence—the fusion and mixture of artificial intelligence, human intelligence, and the intelligence of crowds*. Covering the wide field of innovation automation requires various future research programs. The main focus areas in this paper are related to understanding innovation automation, enabling the way to new management of innovation and ecosystem development. We also propose relevant research themes for the future.

Keywords: Innovation Automation, Innovation, Automation, Strategic Management, Knowledge Management, Innovation Management.

Cite paper as: Harmaakorpi, V., Melkas, H., Porras, J., Pässilä, A., (2023). Will Machines Innovate for and with Us - What Kind of Strategic Themes Could Belong to Innovation Automation?, *Journal of Innovation Management*, 11(4), 143-169.; DOI: https://doi.org/10.24840/2183-0606_011.004_0007

1 Introduction[1]

> "... Yet today we still have a fragmented, often broken innovation process, very reliant on the manual processes, where the human intervention dominates. Can this be changed? Technology must form a greater core of the innovation process. We still are very reliant on stage gate intervention points, often more due to dogma and imposed oversight by committees occasionally meeting. Decisions are determined by the human, based less on hard knowledge or dynamic intelligence, often these have tended to be thinner on the ground to validate concepts and judgement becomes highly personal and reliant on (past) experience. [...] we do need to push this automating the innovation process further, in different ways." (Hobcraft, 2014)

Innovation automation is a novel topic that is being introduced into research. While there is practically no research available globally, the business potential based on innovation automation is likely to be high, as innovation activities are highlighted in all fields and automation enters new arenas. As a research topic, it offers a large number of intriguing sub-topics related to many different research fields, covering a broad area of subjects ranging, for example, from philosophy and humanities to engineering sciences and computer science. Automating different phases of innovation processes, for instance, the utilization of big data and co-creation within innovation processes, is likely to result in major benefits (see Wamba et al., 2015). However, even the first steps on the path towards exploiting these benefits are still practically unknown.

The Internet economy and computer-aided innovation enable significant improvements in the quality and quantity of outcomes of innovation processes; this could be seen as a core competence of future-oriented innovative firms (e.g. Lopez Flores et al., 2015). At present, holistic and sufficiently practice-oriented research to investigate and promote innovation automation is lacking. When we start to investigate innovation automation, how should that be done? The Internet economy has significantly changed the logic of the necessary research. Traditional "research pipes" often do not fit with contemporary business logic research; they are too slow, for instance. In this paper, we focus on the intersection of innovation and automation and the potential they create together.

Targets in innovation automation are significantly different from those of production automation that focuses on having fewer people involved, more outputs, and faster processes. Automation in the innovation context is, inter alia, about maintaining the richness of creative innovation processes while also absorbing a greater amount of data, information, and knowledge inputs and producing more holistic outputs that meet customer needs better and are faster on the market. Numerous tools and applications exist for idea generation and other relevant phases, but innovation is not an automatic funnel. Idea selection and successful market implementation are complex and highly intuitive endeavors. This paper builds on a broad, open and holistic approach to innovation that necessitates an open view of how innovations are generated and developed, crossing interfaces between research fields and sectors, catching trends and turning them into needs and requirements, and encouraging creativity (see also Hautz, Seidl and Whittington, 2017). The paper builds a novel academic "playground" for the research and strategies on innovation automation and presents future research directions (Appleyard & Chesbrough, 2017). The aim of the study is to outline the characteristics of innovation automation and define the future strategic themes in it.

1. This paper is based on the authors' ideas and work that formed the basis of the Strategic Research Agenda on Innovation Automation accepted by the Board of Directors of Digile Ltd. (a former strategic expertise center) in Finland in November 2015. Used with permission.

The research questions are (i) what are the strategic themes of innovation automation? and (ii) what are the strategic research themes in order to elaborate strategic themes further?

2 Research approach

2.1 Research context and methodology

This research was conducted in a practical context. First, it is necessary to briefly explain one Finnish innovation policy tool in order to understand the context. To promote innovation, some years ago, Finland's government decided to found so called Strategic Centres for Science, Technology and Innovation for the most valuable clusters. Companies were founded to coordinate the actions, and science players of the clusters were the shareholders of the companies. The representatives of the main players formed the boards of the companies. The theoretical and empirical work for this current study was done for Digile Ltd., the company coordinating the Strategic Centres for Science, Technology and Innovation for the information technology cluster. Digile Ltd. coordinated its own work with Strategic Research Agendas (SRA). The strategic challenges of innovation automation were seen by its board as a novel and interesting area for a new SRA. Therefore, it started and guided a process for writing an SRA for this field. One of the authors of this article was a member the board and all of the authors of this article were leading the writing group of the SRA. The SRA document included finally 65 pages and gave – together with the writing process - the basis for this research article. This study can be considered constructive action research. The method used was close to the "science by doing" approach, where practice and theory create new, personally experienced, tested and interpreted knowledge (Sydänmaanlakka, 2003). However, a thorough theoretical assessment forms an essential part of the study. Kolb's cycle (Figure 1) of experimental learning is very close to the process effectuated during this research. Originally, Kolb's cycle was designed for experimental learning at the individual level. However, it was used in this case for collective learning of expert groups emphasising reflection (cf. Dewey 1933/1998; Boud et al. 1985; Vince, 2002). Reflection has been an essential part of our research strategy (see e.g. Fook, 2010).

In the above-mentioned context, constructive action research with cooperative inquiries was seen as a justifiable approach for the present study (see Heron, 1996; Reason & Bradbury, 2001). Constructive research produces constructs. Developing a construct means creating something new that is deviant from earlier constructs. Constructive research can be seen as a form of applied research. The aim is to achieve, from a certain point of departure, a desired result. Therefore, constructive research can be defined as a normative approach. An essential part of constructive research is that it is closely based on existing knowledge, and the novelty and functionality are demonstrated. In Figure 2, a presentation of Kasanen et al. (1991) of the nature of constructive research is depicted.

Constructs can be built in several ways. One common way is that the researcher takes an active role in steering the process in real action where the construct is built and its applicability is demonstrated. This kind of a research method can qualify as action research. Action research can be defined as a term "for describing a spectrum of activities that focus on research, planning, theorizing, learning and development. It describes a continuous process of research and learning in the researcher's long-term relationship with a problem." (Cunningham, 1993: 3.) Constructive research and action research are especially applicable together in the empirical part of the present

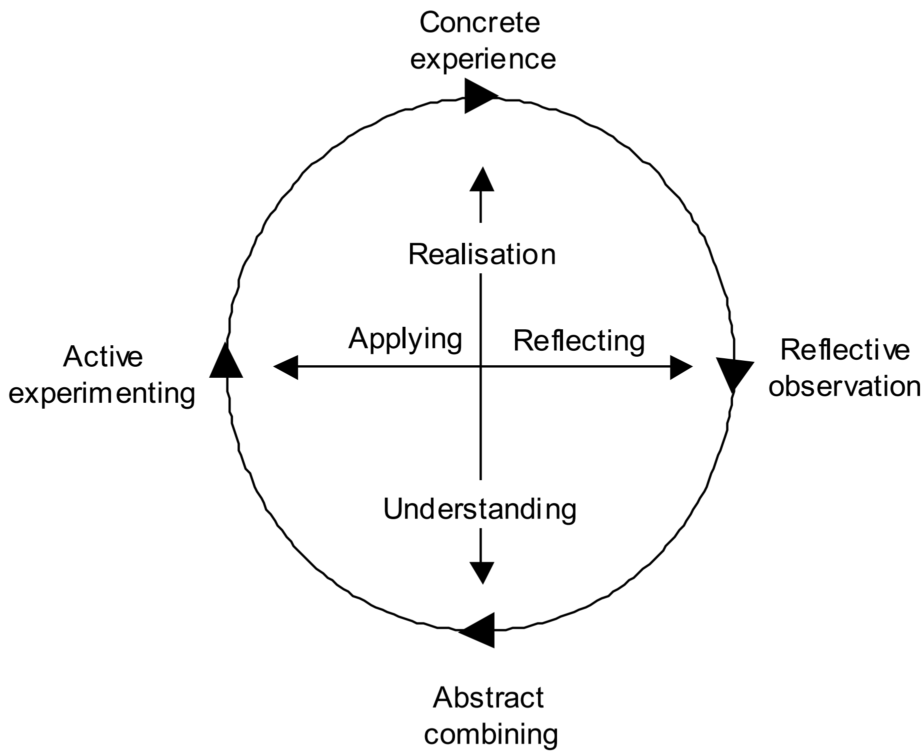

Figure 1. Kolb's cycle of experimental learning (Järvinen et al. 2000: 90).

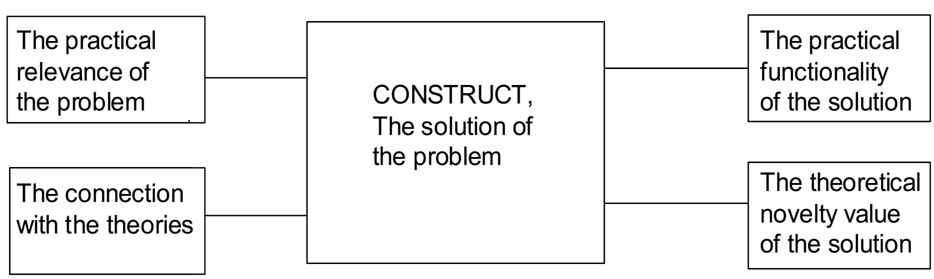

Figure 2. The basic parts of constructive research (Kasanen et al., 1993).

study. For developing some constructs, for example, policy tools, the active participation of the researcher is often a prerequisite for successful research.

2.2 Research progression and structure of the article

The building of the "construct", SRA, took nearly one year. First, Digile Ltd. board opened a call for new SRA candidates. Each of the candidates gave a presentation in a foresight seminar getting comments and ideas from the experts. Further on, the candidates presented their proposals in a board meeting. The board chose innovation automation SRA to be further elaborated. The organization leading the writing process was chosen at the same time.

Building the SRA started with an intensive study of the background theories of the phenomenon by the key authors. The aim was to become familiar with the subject in order to be able to organize the first expert workshops. This preparation phase took about two months. At this phase, research proposals concerning potential future activities under the innovation automation SRA 'umbrella' were also collected. Altogether 17 proposals were submitted, showing a remarkable interest in the subject.

The first two expert workshops were held in two Finnish cities. The experts were invited from the Finnish universities and universities of applied sciences. Besides experts in information technology, innovation experts from many other fields were invited, since a holistic picture of the subject was needed. A lot of valuable information was gathered in the workshops, and the characteristics of strategic and research challenges in innovation automation were unveiled in a deeper way.

After the expert workshops, serious writing of the SRA continued by the writing group for two months. The process was strongly guided by the ideas gathered in the workshops, and their synthesis. It included intensive periods of new theoretical assessments. This phase lasted for about two months ending at a two-day expert writing workshop. Besides the named writing group, the participants included those experts from the first workshops who showed the biggest interest in the subject. After the workshop, the structure of the construct was consolidated.

In the final phase, the SRA was completed, and the remaining gaps were filled. The SRA was also discussed with the Academy of Finland getting a good reception in the main funding organization in Finland. Finally, the board of Digile Ltd. approved the innovation automation SRA nearly a year after the beginning of the process.

Thus, building the construct included intensive phases shown in the Kolb's learning cycle and fulfilled also the requirements of building a construct in context. The construct is the same in this current study. The structure of the article is as follows. The fundamental concepts of the article are first presented and defined. Following this, it is outlined what the phenomenon of innovation automation could be all about. The main strategic themes of innovation automation are defined, including the challenges and opportunities in those. The most important future research fields are presented. Finally, the conclusions for different levels are drawn.

3 Our view of innovation automation

> "What you have now is a set of data streams that will allow you to automate your company's innovation priorities. The data is reflecting what needs to be changed in your product to make it perform its functions in ways that are better suited to different types of users. [...] The likelihood is that innovation programs in the future will be much better coordinated within a system, and they will be dictated by algorithms rather than decision making." (Shaughnessy, 2015)

While it is not possible to provide an account on the state-of-the-art of innovation automation in the traditional sense, this section outlines the foundation for the concept and directions for the future.

3.1 Foundation for the concept of innovation automation

Innovation automation has not previously existed as an independent research topic. The at least partly relevant literature including both the concepts of innovation and automation focuses on, for instance, human-computer interaction (or human-machine cooperation) and the importance of tacit knowledge to innovation (e.g. Senker, 2008; Argote & Levine, 2020). Parasuraman (2000) noted years ago that an emerging knowledge base of human performance research can provide guidelines for designing automation that can be used effectively by human operators of complex systems. Parasuraman's questions of which functions should be automated and to what extent in a given system are also taken into account in this paper, although his views somewhat emphasize risks and negative impacts. In his view, the human performance consequences of particular types and levels of automation constitute primary evaluative criteria for automation design. Four human performance areas are considered—mental workload, situation awareness, complacency, and skill degradation. Secondary evaluative criteria include such factors as automation reliability, the risks of decision/action consequences and the ease of systems integration. In addition to this qualitative approach, quantitative models can inform automation design. The integration of qualitative and quantitative approaches is important for future research. While Parasuraman's research did not focus on innovation automation, designing innovation automation for effective human use also calls for the integration of qualitative and quantitative approaches.

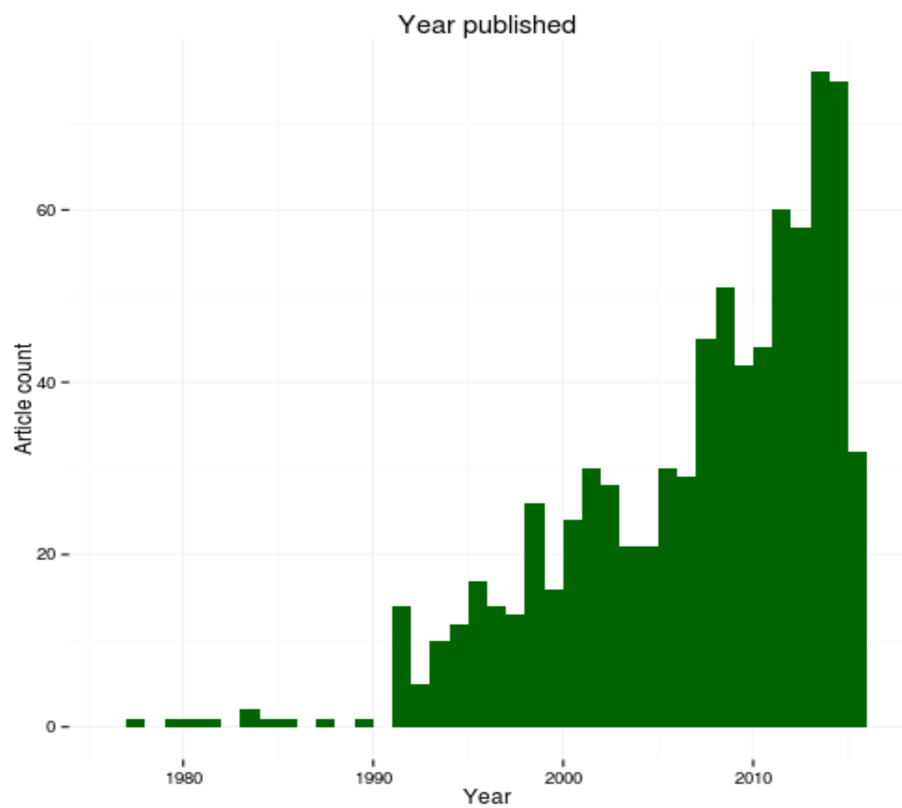

Figure 3. Articles linked to the keywords innovation and automation.

A literature search on innovation automation was performed for this paper with the help of an analysis on the records downloaded from Web of Science. The analysis (for further details concerning the method, see Knutas et al., 2015 and the Nails project[2]) identifies the important authors, journals, and keywords in the dataset based on the number of occurrences and citation counts. This search shows that extant research linked to the keywords innovation and automation does not focus on innovation automation in the sense discussed in this paper, but instead is limited to more traditional contexts, such as the automation of industrial processes. Thus, innovation automation provides a novel research topic and development area. Figures 3 and 4 present the results of the search but should be interpreted with caution, as they did not focus on the concept

2. http://nailsproject.net/

of innovation automation itself, as noted above. In a few years, the situation is likely to be different.

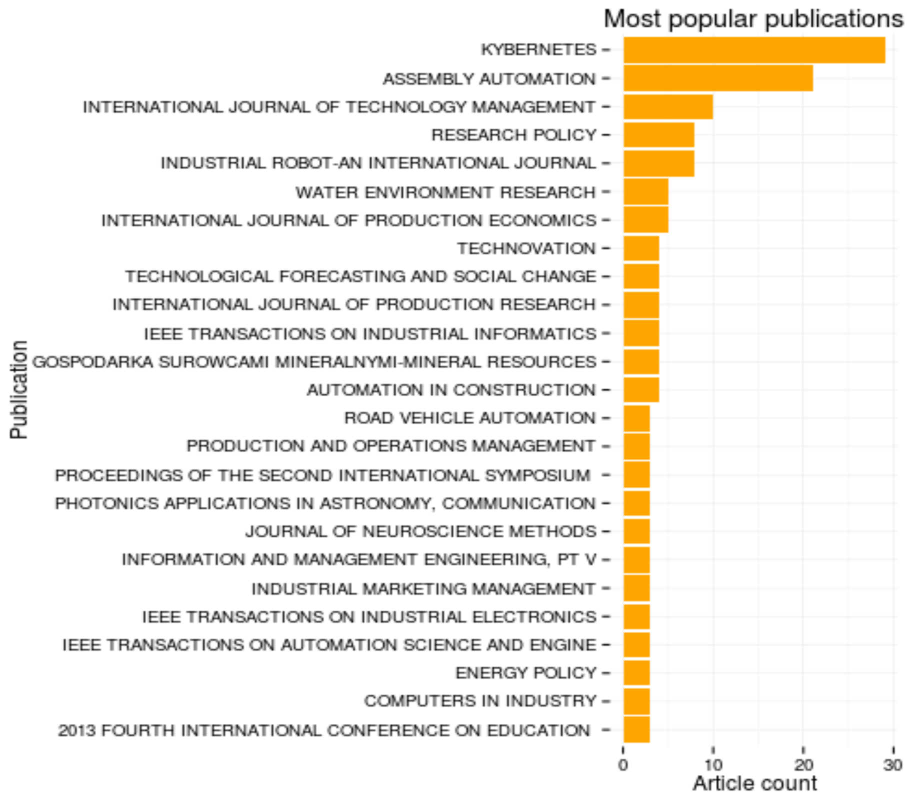

Figure 4. Most popular publications linked to the keywords innovation and automation, sorted by number of published articles in the dataset and by the total number of citations.

New concepts are usually focused on by searching for differences and factors that distinguish them from older concepts. In many cases, it would be useful to search for links and similarities between concepts, as drawing the lines may be artificial. In the implementation, the concept of innovation automation itself also requires consolidation and "clearance" in research. An important point is to cherish the understanding of innovation that has widened in recent years by focusing on the variety of innovation types, rather than merely technical products, for example.

3.2 The vision of innovation automation

This paper is based on looking at *innovation automation as the efficient and effective use of co-creative intelligence—the fusion and mixture of artificial intelligence, human intelligence, and the intelligence of crowds.* Innovation automation is aimed for a new kind of operational environment characterized by changing business logic and new kinds of entrepreneurship (micro-enterprises, social and other networks, ecosystems, platforms, technology adjacencies) (Moore, 1996, 2006; Adner, 2006; Rinkinen & Harmaakorpi, 2019). In this environment, expertise does not depend on organizational boundaries. Product development processes are no longer standardized; companies' R&D departments may vanish, and traditional R&D&I thinking needs to change (Adner & Kapoor, 2010). The wealth of information and knowledge available creates many opportunities, even too many. Generations' values are also changing, and there are significant differences in values across human generations (Kirchmayer & Fratričová, 2020).

The Internet economy has changed the economic environment remarkably. It has been said that everything that can be digitalized will be digitalized . The need for speed in innovation processes is increasing in the Internet economy. The time required to create certain types of innovations in platforms is turning into days or weeks instead of months or years. In the Internet economy, the world is becoming more and more global and complicated. As a result, we will have increasingly challenging problems to solve. There will be more and more heterogeneous and interdisciplinary information to include to the innovation processes (Parjanen et al., 2010). Crowds are increasingly more subjects than objects in innovation (Salminen, 2016). The Internet economy enables us to have a considerable number of people involved in our innovation processes practically online.

Big data is still a vastly unused potential in innovation processes (McAfee & Brynjolfsson, 2012; Lycett, 2013; Ylijoki et al., 2019). Digitalization is an enabler for datafication that leads to big data, the use of vast, fast changing sets of highly variable data (Dutta & Bose, 2015; Ylijoki & Porras, 2016). A major trend in the future will be building algorithms to use big data in different phases of innovation. The Internet economy enables us not only to better follow the market demand and trends, but also to create market demand. That can be done, for example, using social media during the whole innovation process from ideas to prototypes. User-aided prototyping will be combined with computer-aided design and prototyping. 3D-printing will allow us (in the context of product innovation) to produce prototypes during the innovation process. This paper views innovation automation as adapted to this novel environment and as being strongly related to and depending on, first and foremost, the acquisition, refinement and transformation of information and knowledge (Figure 3). The focus is on four types of knowledge:

- The giant space of bits, available for data mining—data and information
- *Codified knowledge* — processed versions of the data and information, put in context, i.e., for instance, "big data" analyzed with algorithms as data-mining tools
- Assessment of needs concerning what knowledge should be considered in those algorithms. This approximates tacit and self-transcending (*highly future-oriented*) knowledge.
- Implementation of the innovation process itself as the interaction between people (and AI agents), with the help of technology. The aim is to speed up the process and improve quality. This is also a playground for *tacit* and *self-transcending knowledge*.

The knowledge-based view on innovation automation is described in Figure 5. It is based on arguments from phenomenology of Husserl (see Welton, 1999) and Heidegger (1962) as well as characteristics of semantics of possible worlds by Hintikka (1962).

The initial themes for innovation automation research and development are described in the later sections of this paper. The following sections focus on the main elements of Figure 5. Another view is based on business implementation. Figure 6 illustrates this view. The upper route, labeled as "business trial path" describes the pathway we aim to search for in the research. Innovation automation may have a role to play in creating or finding out about phenomena, or in providing "pulses" on the upper route (and even the lower route). The initial themes, approaches and methods are described in the later sections of this paper.

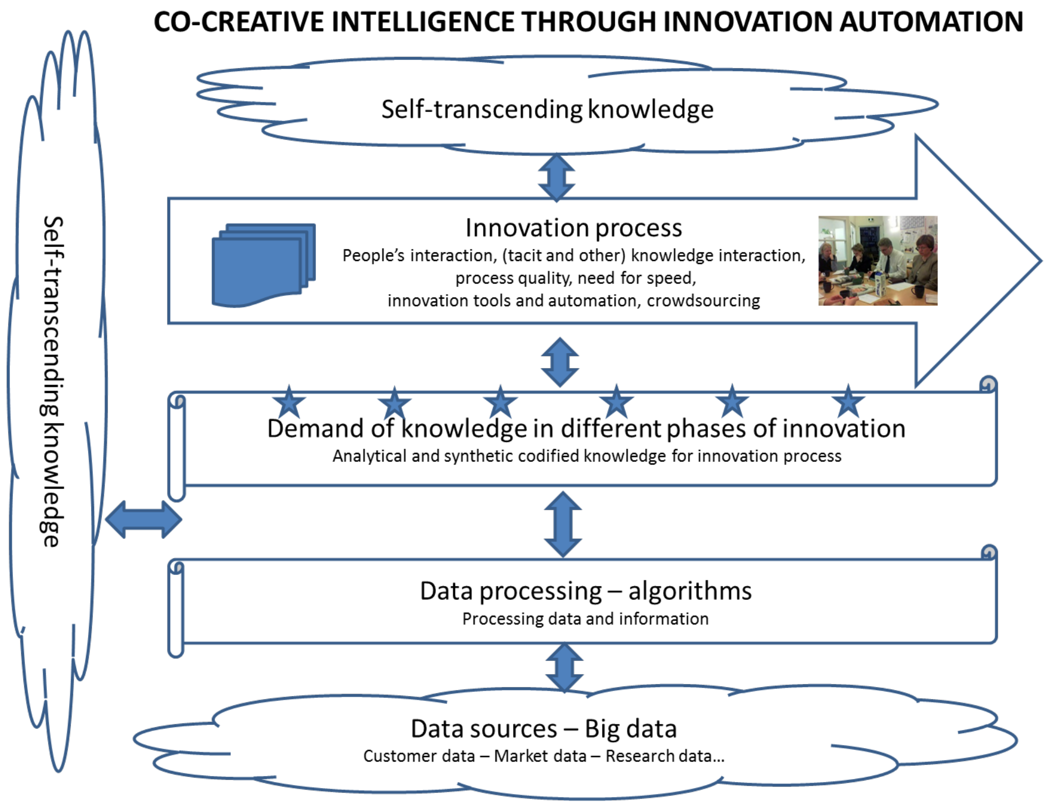

Figure 5. Co-creative intelligence through innovation automation.

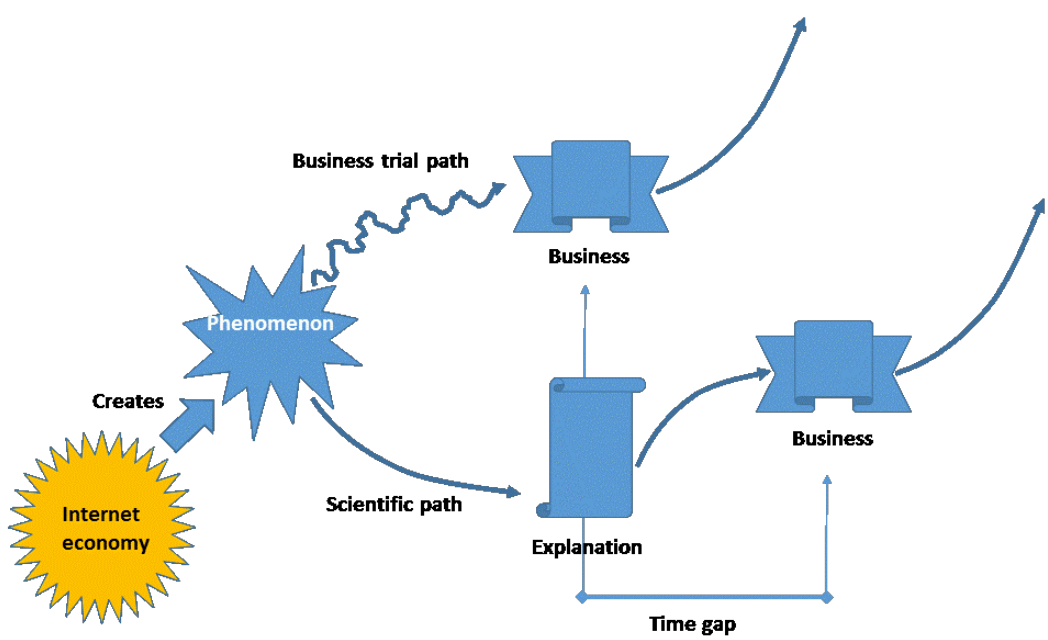

Figure 6. The Internet economy and business trial path (illustration: Reijo Paajanen).

4 Main themes of innovation automation strategies

Four themes were identified for innovation automation based on the workshops: (i) acquisition, refinement and transformation of information and knowledge, (ii) people's interaction and knowledge interaction in innovation processes, (iii) innovation ecosystems, and (iv) identified strategic challenges and opportunities. These themes are further discussed in the following subsections.

4.1 Acquisition, refinement, and the transformation of information and knowledge

Acquisition of data has changed enormously in the Internet economy. In this paper, the focus is not so much on producing data (IoT or digitalization of services), but on utilizing existing and future data, as much as possible. Moreover, the hierarchy of knowledge-related concepts is highlighted; from data all the way to understanding.

Information and knowledge are neither homogeneous nor stable phenomena in any environment, and especially not in the context of innovation. Most scholars (e.g., Becerra-Fernandez et al., 2004; Davenport, 1997) refer to a datum as the most basic descriptive element. Whether it is symbolized as a number, text, or figure, a datum essentially represents a perception or measurement about some object of interest. By itself, a datum's value typically lacks content, meaning, or intent. Although some use the term data interchangeably with information, others consider information to be more than just data. They view information as the output of some process that interprets and manipulates data into some prescribed format. Finally, while some view knowledge as information that has been further enriched so its value, context, and meaning are enhanced; others consider knowledge as being intrinsically different from either data or information products. The idea that knowledge is more than information stems from the notion that knowledge is more a process than a product. The knowledge process occurs when an individual mentally synthesizes an assortment of inputs: information, experiences, beliefs, relationships, and techniques to determine what a specific situation means and how to handle it (Becerra-Fernandez et al., 2004; Pierce, Kahn & Melkas, 2006).

This knowledge process that consists of acquiring, refining and transforming various inputs is central in this paper as the prerequisite and bridge to innovation automation. Organizations' success and survival are widely seen to depend on their capability to create new knowledge and then innovations. Collective learning processes are also emphasized in generating innovations. In order to foster innovations and strengthen their effectiveness, it becomes important to integrate different types of knowledge, competences and experiences into a cooperative perspective (Parjanen et al., 2011). This emphasizes the importance of knowledge creation and management, not only at the organizational level, but also at the network level (Harmaakorpi & Melkas, 2005; Uotila et al., 2005). Knowledge used in innovation processes can be categorized in several ways. A much-used dichotomy divides knowledge into explicit and tacit knowledge, the former relating to knowledge expressed as words or numbers, being thus codified and well defined, and the latter expressed as insights being thus highly personal and hard to formalize (and transfer) (Nonaka & Takeuchi, 1995; Harmaakorpi & Melkas, 2005). This kind of a dichotomization is also often criticized. For example, Howells (2002), citing Polanyi, argued that knowledge can be understood rather as a continuum between wholly explicit knowledge and wholly tacit knowledge, and that tacit knowledge, situation and locational context play a significant role in the use and diffusion of codified knowledge.

Scharmer (2001) discussed "self-transcending knowledge" that can be described as tacit knowledge prior to its embodiment. Such knowledge implies the ability to sense the presence of potential, to see what does not yet exist. Scharmer elaborated the concept with Michelangelo's words about his famous sculpture: "David was already in the stone. I just took away everything that wasn't David". The ability to see a David where others just see rock is the essence of self-transcending knowledge (2001). Scharmer also used the iceberg metaphor (see Figure 7) to illustrate the essence of the three types of knowledge. Above the waterline is explicit knowledge

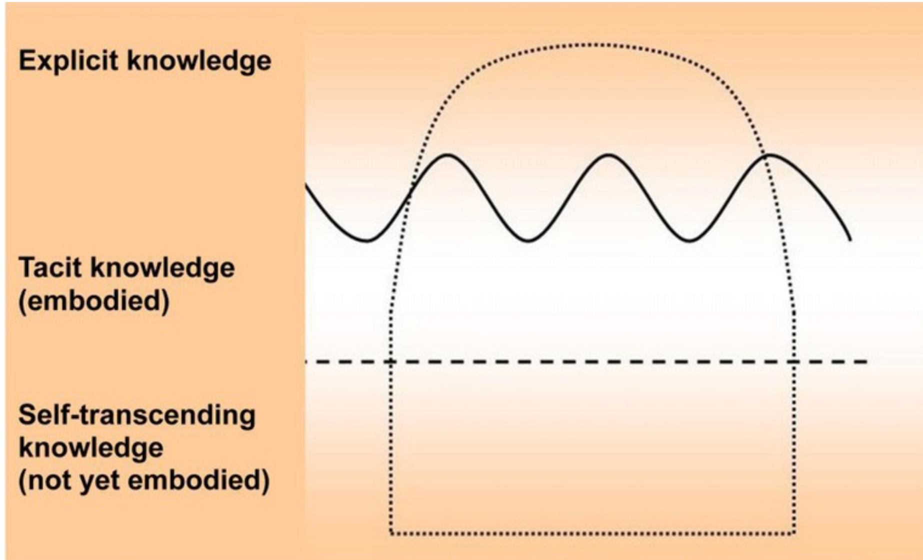

Figure 7. The iceberg model of the three forms of knowledge (Scharmer, 2001, p. 70).

that is least difficult to disseminate and distribute. Below the waterline are the two types of tacit knowledge: first, below the waterline, but still visible is tacit embodied knowledge, and below that, somewhere in the darkness, without a seeable form is self-transcending knowledge. Both these forms of tacit knowledge are very difficult to disseminate and transfer from one part of the organization to another. Once the importance of self-transcending and tacit knowledge is realized, one begins to think about innovation in a wholly new way. Creation of new knowledge is as much about ideals as it is about ideas – and that fact fuels innovation (Takeuchi, 2001). In this paper, the knowledge-based view is central (see also Chesbrough, 2017).

4.2 People's interaction and knowledge interaction in innovation processes

The discussion of knowledge creation and management has gone through an interesting evolution over the years (Scharmer, 2001). During phase I, the primary focus was on explicit knowledge, information technology solutions, and processing of information. During phase II, the process of knowledge creation took precedence. Knowledge was conceived of as tacit and as a process (not a thing). Finally, during phase III, attention is focused on the thought conditions that allow processes and tacit knowledge to evolve in the first place. This phase III allows also for a wider view of innovation itself as well as novel methods of knowledge creation focused on people's thought conditions. In this paper, we focus on all three; innovation automation is seen from a holistic perspective, not merely technological.

When different types of knowledge are discussed in research contexts, the discussion often focusses on explicit knowledge and (embodied) tacit knowledge, only. For example, Nonaka and Takeuchi's (1995) well known SECI model of knowledge creation did not include self-transcending knowledge (the concept was introduced only later), but focused on the creation of tacit and explicit knowledge as well as on the interaction between explicit and tacit knowledge in collective learning. In their four-phase model, a collective learning process increases knowledge, and knowledge conversion takes place in certain forums or arenas (ba in Japanese) that may be concrete or virtual places. The model had the aim of causing a learning spiral where a collective learning process increases knowledge in the network. Different kinds of knowledge processes need different kinds of bas. Harmaakorpi and Melkas (2005) and Uotila et al. (2005) later on incorporated self-transcending knowledge into an extended SECI/ba model (the "rye-bread model"; see Figure 8). The model describes the process of how knowledge and understanding are produced and converted.

The "rye-bread model" extends the original model of SECI/ba by adding two new phases of knowledge conversion:

- conversion of self-transcending knowledge to tacit knowledge
- vice versa, conversion of tacit knowledge to self-transcending knowledge.

These processes are both collective and individual. They take place in two bas:

- 'Imagination ba': visualization (from self-transcending to tacit); self-transcending knowledge is embodied from the abstract to visions, feelings, mental models, etc.
- 'Futurizing ba': potentialization (from tacit to self-transcending); tacit knowledge is disembodied and forms the basis for sensing the future potentials and seeing what does not yet exist.

This model is a conceptual description of how to promote collective learning and innovativeness by means of collaborative knowledge creation. When promoting innovation automation, these different phases shall be taken into account.

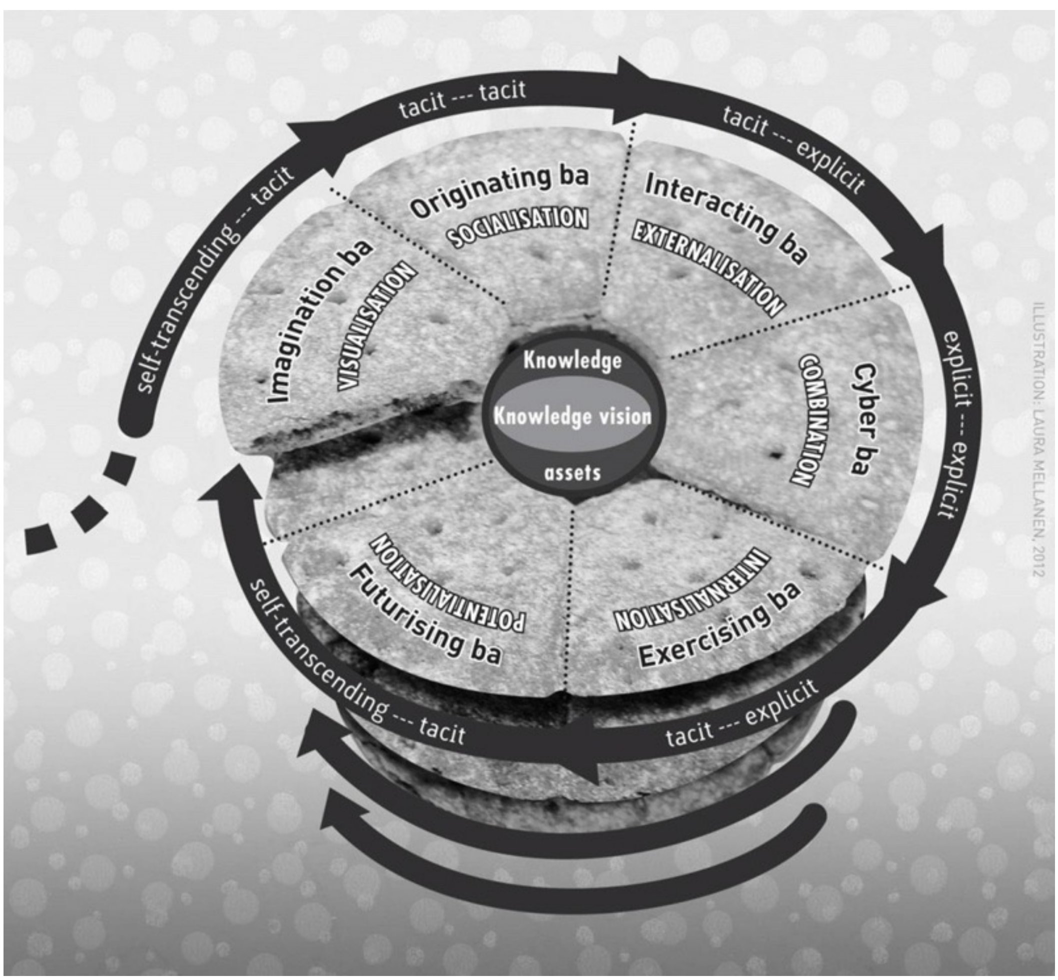

Figure 8. The rye-bread model of knowledge creation (Harmaakorpi & Melkas, 2005; Uotila et al., 2005; new illustration: Laura Mellanen, 2012).

True acknowledgement of the three forms of knowledge (self-transcending, tacit and explicit) presented earlier also challenges the traditional approaches to innovation. Inclusion of all the three forms of knowledge into an innovation process necessitates the development of a process that is participatory and action-oriented – giving time not only to imagination but sometimes also to odysseys and lingering. The need to linger highlights multi-temporal elements in knowledge creation. This flexible temporality is still a relatively weak signal, but an important issue that is gradually understood better and has a lot of future potential (e.g., Baungaard Rasmussen & Wangel, 2007). Lingering may also be associated with presencing (Scharmer, 2009), a holistic way of being present; the blending of sensing and presence that Scharmer finds crucial in leadership and management praxis.

Knowledge creation processes like these cannot be forced into the format of basic innovation management procedures (i.e., defining a problem, generating possible solutions, testing them, selecting and implementing the best available one, and measuring it). The three forms of knowledge necessitate a fundamentally different kind of knowledge creation process to take place; a creative process that is focused on finding and creating, aiming to transform something not yet existing into existing, and to give it a figure or voice. It is about finding possible worlds and building up a community, where people – employees, for instance – can be (active) actors, who are creating a meaning together. Even though this process cannot be controlled from the outside, it is still possible to facilitate it and create suitable circumstances for the creation of the necessary bas. It calls for participation; the starting point being that the surrounding world, common experiences, values, beliefs and interests can be shared, pondered and processed (Boal, 1995; 1996). We are thus dealing with change management, processes of inner knowing and social innovation that facilitate transformation of observations into intuitions and judgements about the present state and ideas or decisions about the future. This translates into a novel innovation culture in organizations. This paper highlights creativity in innovation processes and aims to give space for innovation automation even in such processes that do not focus on traditional problem-solving.

4.3 Innovation ecosystems

Applying the ecosystem concept to a business context was made popular by James F. Moore in 1996, drawing from organizational ecology (Freeman and Hannan, 1983). Moore stated that competition had changed from the traditional head-to-head situation and that this change should be examined in a new way. According to Moore (1993), firms should not be seen as a part of an industry but as a part of an ecosystem where companies cooperate, compete and co-evolve capabilities around a new innovation. He defined a business ecosystem as 'a type of a business network, a collaboration to create a system of complementary capabilities and companies' (Moore, 2006). Ecosystems can be regarded as value networks in which the value is co-created (Peppard and Rylander, 2006). Typically, these network relationships are loose, which makes ecosystems adaptable as fruitless connections that can be cut and new ones formed at a rather fast pace (Iansiti and Levien, 2004). Basically, a business ecosystem can be opened up to all possible contributors and participants and thus create an organizational form of 'distributed creativity'. Moore (1993) defined four different stages in the development of business ecosystems: birth, expansion, leadership and self-renewal or death. As in biological ecosystems, each member of the system shares the fate of the whole ecosystem (Moore, 1993; 2006; Iansiti and Levien, 2004). From the perspective of an individual entrepreneur however, it is necessary to maintain the balance between an independent entrepreneur mindset and an ecosystem mindset since there might be conflicts between the ecosystem's and the individual members' successes (Nambisan and Baron, 2013). It is crucial to be able to consider the whole business ecosystem when making strategic choices and decisions within an organization (Adner, 2006). Business ecosystems may also include bottlenecks to innovation in a particular location of the ecosystem, which poses challenges for value creation and ecosystem management (Adner and Kapoor, 2010; Rinkinen & Harmaakorpi, 2019). These ecosystems are first and foremost global. It is generally difficult to define the ecosystem boundaries, whether they are geographical or not. When mapping an ecosystem, one should try to identify the organizations whose futures are most closely intertwined and who share certain dependencies (Iansiti and Levien, 2004; Majava et al. 2020). Santos and Eisenhardt (2005) sought to contribute to the solving of the organizational boundary problem in business ecosystems by developing four conceptions of organizational boundaries (efficiency, power, competence and identity) by which the boundaries can be sketched. Ecosystems cross a variety of industries and contain several ecosystem domains (Iansiti and Levien, 2004). The ecosystem may share these domains with other ecosystems. Ecosystems may also consist of independent niches that can be developed within an ecosystem by specialized new ventures (Moore, 2006; Zahra and Nambisan, 2011). Moore (2006) also discussed the concept of space as a domain for business opportunity. It is a space for a future business activity that does not necessarily exist yet or is in its early beginnings (see also Figure 9). By skillful implementation of this paper, an objective is to create new, not yet existing spaces with the help of innovation automation.

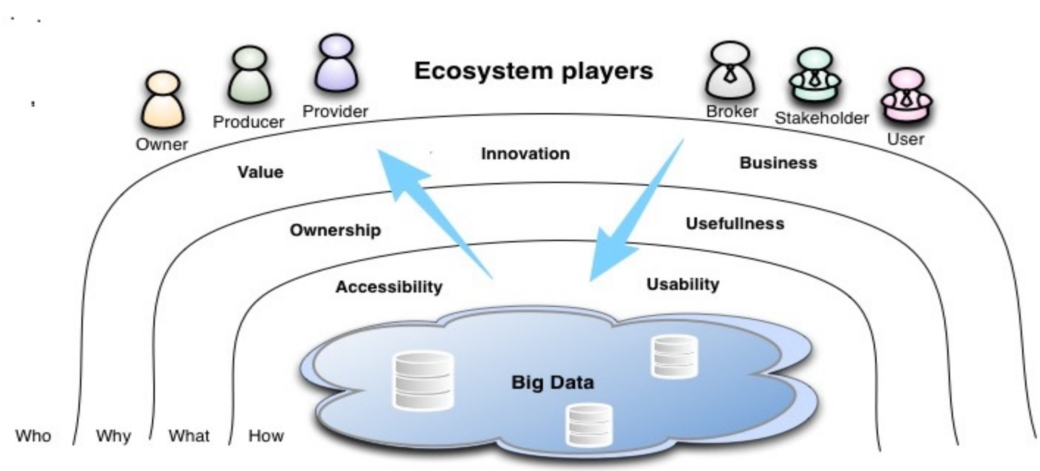

Figure 9. An exemplary vision of the big data ecosystem (illustration: Jari Porras).

As the ecosystem approach is fairly new policy-wise, business ecosystem literature does not offer many suggestions for the policy implications of this approach. Moore (1993) noticed the possible societal downside of ecosystem evolution and notes that we must find ways to help individuals within dying ecosystems to shift to new, emerging and more vital ecosystems. It is fairly obvious that as ecosystems consist of several, often rather small, firms, policies should draw special attention to the role of small firms in innovation, economic growth and employment. Moore (2006) also stressed the importance of ecosystems being able to address new business domains. He argued that helping ecosystems (by for example, with financing) to address new 'opportunity spaces' is important for a society that hopes to attract entrepreneurs and be innovative. Wessner (2004) listed some innovation ecosystem policy lessons from the United States. He advised focusing innovation programs on the individual entrepreneur, basing government fund granting on a competitive basis, improving markets by encouraging private initiative, fostering a culture of innovation and matching policies to market realities. However, these suggestions seem quite general and do not offer anything particularly new to innovation policy discussion. Peltoniemi and Vuori (2004) stated that if we follow the theory of ecosystems as complex, self-organizing and self-sustaining systems, then no government interventions should be needed for them to survive in global markets. This paper aims to contribute to creating a resilient innovation automation ecosystem.

4.4 Strategic challenges and opportunities: conclusion

The automation of knowledge work is going on in various areas. Through the implementation of innovation automation, we may find novel areas for it and promote automating knowledge work for innovation, not against innovation; to the extent that it can engage people more effectively, especially in an environment where data are scattered in multiple sources and in various forms. Using, for instance, data science and big data technologies skillfully to enable the cross-analysis of multimodal and distinct sets of information and find insights and connect individuals and groups in new ways has become essential (Melkas et al., 2016). Capturing and understanding the major global trends in technology or society evolution is necessary for innovation automation. Users' role is also central. They are not only people, but may also be gadgets or networks that utilize and process data and information. In this paper, the human view is also highlighted to advance the inclusion of new people into the sphere of innovation activities, not just as sources of data and objects, but also as subjects (Hennala et al., 2012). Users' needs and habits continue to change rapidly in the digital world. The different generations of users are products of their own time and environment; user needs guide the technology and the technology shapes the users.

Innovation is still studied by many mainly as a decision-making and problem-solving process with its roots in engineering—from this perspective, innovation is defined as an analytical, linear project, aimed at solving existing problems. Innovation processes are also affected by issues that cannot be solved in a linear and analytical fashion, and the efficient use of innovation automation should be able to address those as well. The interpretative approach to innovation (see Lester & Piore, 2004) is not widely understood in the field of innovation, but with innovation automation, it might be supported as well. The interpretative innovation process requires the willingness to accept multiple viewpoints and a lack of universal truths, and this is where innovation automation may be of help by creating, bringing up, and consolidating multiple suggestions and proposals (Pässilä et al., 2015). Innovation automation also concerns the ecosystem level; new, emerging ecosystems are needed to compensate for and/or support old ones. Ecosystems consist of various stakeholders (firms but also many others) and need to be able to address new business domains (Rinkinen & Harmaakorpi, 2018). Helping an innovation automation ecosystem to address the new "opportunity space" identified in this paper corresponds to the view of ecosystem building as important for a society that hopes to attract entrepreneurs and be innovative.

Rather than providing or seeking one right answer, we are interested in creating various possible worlds and scenarios for making sense and coming up with solutions to wicked problems. Reflection is a powerful "tool" for that. The theory of reflection emphasizes lived experiences and how to gain knowledge of them. Reflection is focused on making sense of perplexity instead of trying to control it (e.g., Vince, 2012; Reynolds & Vince, 2004). Recent innovation studies (Sveiby et al., 2012; Hasu et al., 2012) suggest that reflection is a key process of innovation, especially when reflection is understood as a collective way of learning and gaining knowledge. The aim of Sveiby et al. (2012, p. 3) is "...to challenge contemporary innovation research by problematizing its underlying assumptions and promoting a more nuanced way of considering the consequences of innovation...." In saying this, they point out the need for critical innovation policy at the macro-level and for critical innovation activities in meso- and micro-level processes.

Therefore, one fundamental element of innovation automation is claimed to be critical reflection, especially on a collective rather than individual level. To create innovation automation, we therefore need to "unsettle conventional practices" (Cunliffe & Easterby-Smith, 2004) and question taken-for-granted components of organizing. This leads to a reflexive stance that will help contribute to knowledge and future benefits and changes (Pässilä & Vince, 2016) when exploring, for instance, how we create a multidisciplinary definition of what innovation automation means based on various assumptions from various disciplines.

Innovation automation represents a next generation of automation that has structural implications. The automation of knowledge work, for example, will impact business models, roles, processes, policies, organization structures, and operating models. While the benefits of a broader and deeper level of automation are many, leaders must assess the implications and evaluate how they might introduce these new forms of automation. Questions need to be answered, including: What tasks will be augmented? Which will be fully automated? How are roles altered? How are organizational processes impacted? As traditional enterprise structures are re-imagined, the impacts can be profound (Diana, 2014; Sherringham & Unhelkar, 2020).

As new market entrants, Internet companies, and start-ups leverage next-generation automation, the disruptive pressures on traditional companies mount. Addressing these disruptive pressures is one of the compelling reasons for leaders to analyze automation scenarios and understand both their application and implications. But there are other benefits for businesses, including significantly reduced labor costs, greater flexibility, and reduced time to market. Some companies may find it cost effective to repatriate manufacturing operations and position them closer to the final assembly and consumers. Entirely new business models are possible, and new high-skill employment opportunities may emerge—but so too will the loss of existing jobs. New people can be brought to the sphere of innovation activities, thus advancing inclusion and social sustainability. Other societal benefits are possible across a wide spectrum. Thus, next-generation automation—enabled by combinatorial innovation—is one of those disruptive scenarios that is in our line of sight, but still far on the horizon. As is the case with such scenarios, experimentation in these early days is critical. These promising innovations should be looked at by leaders with an eye towards the structural change that is sure to follow. It is vital to analyze these scenarios, experiment, and understand the responses needed (Diana, 2014; also see Dörner & Meffert, 2015). This paper contains such elements.

5 Results and discussion: Future research strategy for innovation automation

5.1 Overview

This paper builds on a broad, holistic approach to innovation that necessitates an open view of how innovations are generated and developed, crossing interfaces between research fields and sectors, catching trends and turning them into needs and requirements, and encouraging creativity. By fostering a novel innovative culture, speeding up innovation processes and enhancing the innovation of services, we can contribute to companies' success (also see Figure 10 for visualizations). Figure 10 shows how big data and other data could be used to make it possible to come up with innovations even in one day and create demand simultaneously. The main sources are users and crowds. Speeding up things and having time for (creative) slack are combined. It is not merely about automating an existing industrial process, but ethical issues and sustainability can also be taken into consideration by, for instance, providing similar opportunities for different kinds of people to be innovators and new opportunities for presently non-innovative companies in a highly competitive environment.

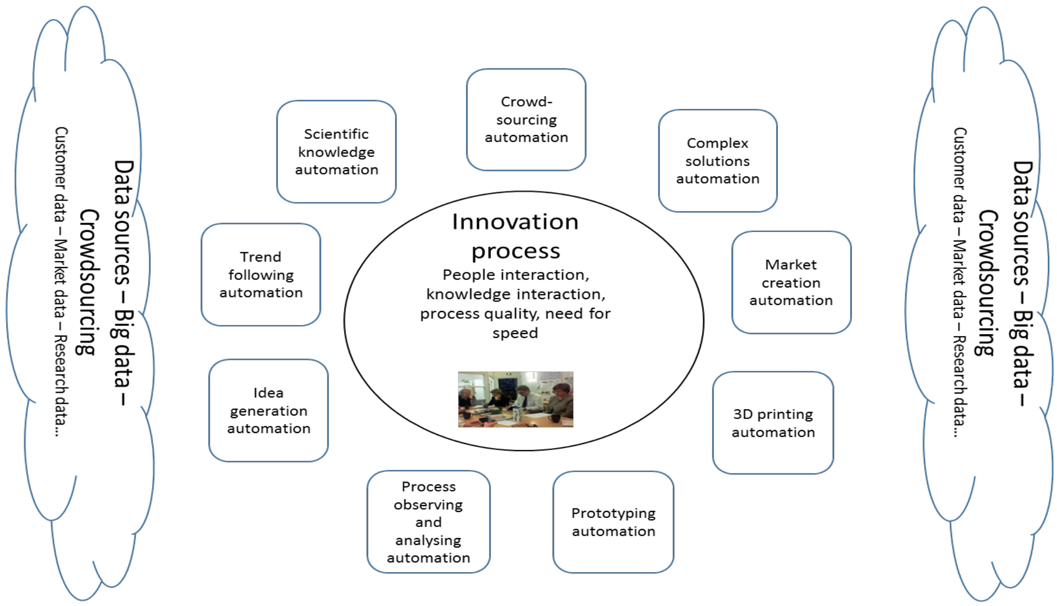

Figure 10. From no idea to prototype in one day by innovation automation—co-creative intelligence and online big data and customer involvement in different phases.

In the following, a narrative is utilized to explain how the innovation automation system could function.

> Peter's responsibility is to create innovations for his company. The trends are changing fast and the lifecycle of products and services is becoming shorter and shorter. Peter's company has designed an innovation automation system including strategic elements for him and his team in order to keep up with the speed.
>
> The first thing Peter and his team do in the morning is to check what the trend-following element of the system tells about the trends in the big data from the social media. After discussion of some interesting trends in the team, it is time to utilize the elements of scientific knowledge automation and idea generation automation. It is important to have access to the scientific knowledge related to the trends, and after that, use automation to cross-fertilize the trends and scientific knowledge.
>
> After these phases, some kind of a seed for innovation could already be slightly visible. It is time to have the interaction with the crowds involved in the 'game'. The elements of crowdsourcing automation and market creation automation take care of that together with Peter's team. The aim is to get the users to innovate with the team, and, simultaneously, enable the lead users to begin to market the nascent innovation within their networks.
>
> One should not rely on the first ideas to be necessarily the best ones. It is time to still look for totally unexpected solutions with the element of complex solutions automation. Highly unconventional opportunities are sought. The element of process observing and analyzing automation is used in this phase to look for new opportunities in the co-creation process of Peter's team. Finally, it is time to make the achieved innovation visible. The elements of prototyping automation and 3D printing automation are included in the innovation process. All this could happen within one single day.

This kind of innovation automation system does not exist yet. Building such a system still needs a lot of multidisciplinary research. Whereas the proposed main research themes are described in more detail in the following, many of the themes are interconnected and have various research areas in common. The whole research field of innovation automation is quite spread out, and covering it requires various future research initiatives. The main focus areas, in our view, are related to understanding innovation automation, enabling new innovation management, and ecosystem development. The research methods need to be assigned skillfully to the different topics.

5.2 Research themes in outlining innovation automation strategies

The main research themes and the future research avenues of innovation automation, as proposed, are (i) data sources and data processing for innovation automation, (ii) interactive innovation processes for innovation automation, (iii) innovation automation ecosystem, and (iv) Joker. The fourth one is deliberately dedicated to surprises and new approaches in this emerging area.

Theme 1: Data sources and data processing for innovation automation

The theme of "data sources and data processing for innovation automation" aims to achieve a better understanding and development of methods and models for innovation support and enabling technologies for innovation automation utilizing data technology. Data are the fuel of many organizations and businesses of today, and data, information, and knowledge are the fuel of innovation processes. Data collection, management, processing, and analysis capacity are fundamental for providing inputs and insights into innovation activities. In this paper, the focus is both on sensing valuable data items and responding to them and getting value from aggregate data.

Theme 2: Interactive innovation processes for innovation automation

Innovation can be seen as a generalized, often non-linear design process in which heterogeneous knowledge items are collected and both requirements (constraints) and solutions (realizations) gradually evolve in parallel. Various, limited viewpoints to this collection alternate and enable the emergence of partial solutions, which compete for acceptance. A potential innovation appears when a consistent solution is found that is shared by a sufficient number of viewpoints (technology, usability, economy, etc.). Interactive innovation happens in a group (society of minds) in which there are different roles (with different viewpoints), and communication among them is essential for the process to converge into an innovation. Due to the nature of co-creative intelligence, we envisage such collaborative processes as seamless interactions between humans and machines, both of whom take on various, purposely defined, roles. In conclusion, interactive innovation processes include a varying overall process with its sub-processes, collaboration, process roles, and enabling technologies.

Theme 3: Innovation automation ecosystem

When presenting the concept of a business ecosystem in 1993, Moore emphasized that innovative businesses rely on different external resources rather than evolving in a vacuum. More specifically, ecosystems are coupled to capital, partners, suppliers, and customers with which they create cooperative networks. Firms should thus not be seen as parts of an industry, but as parts of an ecosystem, where companies cooperate, compete, and co-evolve capabilities around a new innovation. A great number of connected things on the Internet and a great number of people increase the complexity of innovation and requires more adaptive technical solutions, and this will increasingly change the roles of network actors and of the customer in the future, compared to today's industries and traditional business models. In this paper, while highlighting business perspectives, we focus on the wider innovation automation ecosystem that covers the business ecosystem of innovation automation including (i) business model development, (ii) platform-based ecosystems, and (iii) stakeholders in the innovation automation ecosystem.

Theme 4: Joker; innovating with us

This theme embraces areas that are either different from the first three themes or embrace more than one of the three themes. The idea of this "Joker" theme is to create a novel "human-intelligence–imagination–intuition–self-transcending knowledge–intelligent" agent that has environmental, social, aesthetic, and economical sustainability as well as morality in it. Innovation automation could be a learning and reflection process of human beings to become their "best versions of themselves." Beyond innovation automation is a goal to co-create common good. This task links both the humanistic interpretative and natural science worldviews (Figure 11). This kind of a puzzle is like a montage that combines all shapes and sizes of knowledge and provides sketches and guesses as well as aims to foresee how to create a desired future.

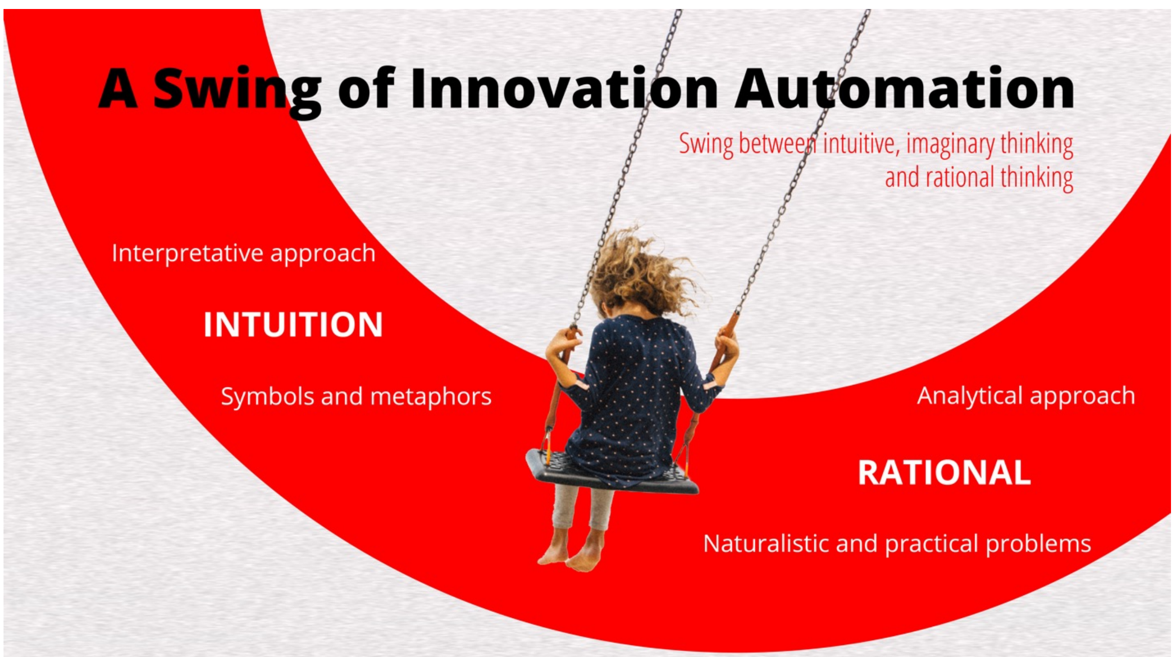

Figure 11. A swing of innovation automation (illustration: Ilona Nousiainen).

Validity and limitations

When building a construct like a research agenda as the solution for the given problem, four conditions have to be fulfilled: (i) the practical relevance of the problem, (ii) the connection with the theories, (iii) the theoretical functionality of the solution, and (iv) the practical functionality of the solution.

The board of Digile Ltd. pondered in many occasions the practical relevance of the challenges included in innovation automation. Since the board members were representatives of the main business players in the field and decided unanimously to start the project, the first condition can be considered as fulfilled. The starting point was that the understanding of the connection with the theories was quite weak, since there was practically no research of the theme; of innovation and automation separately, yes, but not of innovation automation. During the research, theory connections were found and elaborated further with the experts in the field. The novelty is in the synthesis of these theories under the umbrella of strategic themes in innovation automation, not in the individual theories. Finally, the board of Digile Ltd. approved the research agenda unanimously showing the assumed practical functionality of the work done. Although the written research agenda and this current article are not the same, the result in them is practically similar.

Especially due to the explorative nature of this current study, it has a number of limitations. Combining scientific research with practical work has its pros and cons. The researcher, being part of the phenomenon studied and being able to steer the studied development process, enables a quick practical application of the conclusions drawn by reflective observation and abstract combining. The developer's role in a research project also gives a good basis for the applicability of the final results of the study. One of the main risks in the process is that the practical work takes all the time from the theoretical assessment, and a deep understanding of the phenomenon studied remains incomplete. This is a risk that can be avoided by proper planning and scheduling of the phases in the learning cycle. One needs to regularly step back from the practical work and take time for deep theoretical thinking. This method also protects the researcher from being steered by intuitive practical decision-making instead of justified scientific reasoning.

6 Conclusions

By implementing innovation automation strategies, the following breakthrough targets are aimed at.

6.1 Individual, organizational, and market levels

With the help of innovation automation, we may create new markets and attract users with products and services that are increasingly user-oriented. Innovation is often the result of "creative misunderstandings" based on various types of diversity (cognition, cultural, etc.) and intellectual cross-fertilization. Thus, automation will create more disruptive hunches (intuitive ideas) by bringing in seemingly irrelevant and non-connected things and inputs. Creativity and hunches also need to transcend human beings—new conceptual approaches will recognize surprising machines that already deliver a hunch on how to use a particular idea in a given context. Machines can go through options and produce a hunch on how to use the idea strengthening the element of surprise. Creative operations depend essentially on people, but certain phases of them may be aided by automation in a way that makes processes smoother (e.g., documentation, compiling ideas). Skilled automation of creativity-related things leads to new kind of co-creation.

Innovation automation combines creativity and scalability/ repeatability. By means of including automation in certain phases of the creative innovation process, appropriate scalability and repeatability may be improved. This again leads to the improved productivity and effectiveness of innovation activities. With the help of innovation automation, it becomes easier to identify and bring forth present needs: "need of the day". People's thinking has an impact on what becomes a success in the community. Big data on people's thinking can be used as a basis for simulation.

One of the greatest problems in a business environment is to include individuals who are obviously different, or even challenged in their abilities. Innovation automation will enable different approaches for different people, with different abilities, ages, backgrounds, and issues. By improving inclusion, an increasing variety of needs, surprises, and creative ideas will be obtained. Equality in this context means offering equal opportunities by offering customized ways of interacting.

6.2 Ecosystem and national levels

The use of big data, computational algorithms and data-driven cross-fertilization enables more options; trends, hunches, opportunities, threats, to be used in innovation processes - innovation by computation. When developing innovation automation, sustainability perspectives will be taken into account. Socially, economically, environmentally, and culturally sustainable innovation will be advanced. This target is related to the targets mentioned on the first level, above.

New understanding will be produced concerning innovation as a social process, which (fluctuating) roles are being taken, how the actors can be described, and how they collaborate - an innovation automation ecosystem. Actors can be humans, machines, and organizations. The emphasis here is on diversity, fluid environments, and modular but not necessarily linear processes. In addition, it is not sufficient to look at merely innovation automation, but the whole ecosystem around it. Different players of the ecosystem, the ownership of innovation automation, and business values as well as their links to the innovation processes need to be considered.

The breakthrough targets concern the different levels, macro-, meso-, and micro-levels, which are interlinked. The research themes presented also focus on the different levels, but, importantly, with a view towards the whole to be able to reach the aims of this research agenda.

6.3 Concluding remarks

The innovation paradigm has been changing due to a widening understanding of the concept of innovation, ecosystem thinking, new roles of users, and numerous other factors discussed in the previous parts of this paper. Lundvall (2007) emphasized that in the current era, there is a need for both strengthening the science base and promoting experience-based (DUI, practice-based) learning; this is fundamental when it comes to linking the innovation systems to economic development (see also Melkas & Harmaakorpi, 2012; Harmaakorpi et al., 2017). Lundvall also strongly emphasized the importance of human resources. One aspect of globalization is that codified knowledge moves quickly across borders. In this situation, the most localized resource remains people, their tacit knowledge, their network relationships, and their accumulated organizational experiences. All parts of the innovation system that contribute to competence building are becoming increasingly important for national performance.

But how does the national innovation system, or in this case, the innovation automation ecosystem that is created work effectively in the context of ever-increasing global competition and the increased importance of users? While implementing innovation automation, we need to look at the opportunities for novel services, technologies, activities, participants, etc., from the viewpoints of many different theoretical and practical backgrounds. The new multidisciplinary framework must cope with new and potential new qualities of innovation automation through engaging stakeholders from individuals (consumers, clients, workers) to organizations (companies, industry associations) their networks) and public actors (ministries, municipalities, innovation funders). By means of these actions, the aim is to serve the current innovation paradigm change and bring a new flavor of innovation automation to it. When considering scientific and managerial implications we especially need to both (i) produce a theoretical and practical understanding on the role of automation in innovation activities and systems, for the benefit of research, digital service providers, and product and service developers; and (ii) create scientifically and practically proven solutions to digital service development for innovation automation.

Acknowledgements

The authors wish to thank Digile Ltd. for the encouragement to work on this intriguing topic. Thanks are also due to the participants of the Digile workshops in which the topic was discussed.

This work was supported by the LUT Research Platform on Smart Services for Digitalisation (DIGI-USER).

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