ADDITIVE MANUFACTURING AND CREATIVITY ENHANCEMENT: AN UNDERVALUED FORM OF COMPLEMENTARITY

Mattia Pedota[1], Lucia Piscitello[2]

[1]Polytechnic University of Milan, Italy

[2]Polytechnic University of Milan, Italy and Henley Business School – University of Reading, U.K.

mattia.pedota@polimi.it

ABSTRACT

The advent of industry 4.0 dictates a reconsideration of the relationship between technology and work. While robotics and artificial intelligence spread concerns of massive unemployment, other advanced technologies' dynamics of complementarity and substitution with respect to human skills are less clear and less investigated. Building on the system theory of creativity, we focus on additive manufacturing and conceptualise creativity enhancement as a form of complementarity between technologies and skills. We argue that this form of complementarity goes beyond the well-established creativity-supporting role of technological tools, and is particularly relevant to industry 4.0 innovations. We supplement our conceptual framework with a case study-based inquiry into a global leader in the high-end eyewear sector: Luxottica. The empirical findings confirm and enrich our conceptualisation.

***Keywords**: skills, technology, creativity, industry 4.0.*

1. INTRODUCTION

The impact of technological evolution on labour has most often been framed within a dichotomy of substitution versus complementarity. Various declinations of this framework have been adopted to describe, explain and predict the effect of automation and digitalisation on wages and employment of different worker categories in the last decades (e.g. Goos, Manning and Salomons, 2009; Adermon and Gustavsson, 2015). The consensus is that middle-skill workers are the category that is most at risk of substitution, given that robotisation and computerisation can easily perform codifiable instructions, which tend to characterise middle-skill tasks. Conversely, high-skill and low-skill tasks require tacit knowledge in the form of cognition, persuasion, adaptability and empathy, shielding the corresponding worker categories from substitution (Autor, Levy and Murnane, 2003; Autor, Katz and Kearney 2006).

However, recent technological advancements within the realm of Industry 4.0 require a reconsideration of the automation frontier. Machines are becoming surprisingly capable in domains that were thought to be exclusively human, such as driving and complex communication, as Google's driverless car and Lionbridge's Geofluent show (Brynjolfsson and McAfee, 2011). Many studies have inquired into the susceptibility of jobs to these advanced forms of automation, with results ranging from 47% (Frey and Osborne, 2017) to 33% (Pajarinen and Rouvinen, 2014) and a more reassuring 9% (Arntz, Gregory and Zierahn, 2017).

While a consensus on the degree of job susceptibility to automation has not been reached, the need to synchronise technological advancement and skill upgrading is widely acknowledged. This tendency, well-exemplified by expressions like "human factor readiness” (Galaske et al, 2017) and “future readiness” (Botha, 2018), seems to frame human skills at the service of technology, more than the other way around.

Despite the relevance of bridging the skill gap, we claim that there is more to the topic. Technology can be defined as the set of methods and processes allowing humanity to shape the surrounding environment. Thus, it is also a skill-amplifier, rather than simply a skill-requirer.

In order to analyse this aspect of the relationship between technology and skills, we investigate a technology that has both digitalisation and automation components: additive manufacturing (AM). Borrowing constructs from the system model of creativity (Csikszentmihalyi, 1997), we elucidate how technologies may augment creativity through a domain expansion.

Creativity enhancement is vital for firms’ survival and success (Cummings and Oldham, 1997). From an organisational perspective, technology has straightforward creativity-enhancing properties: it links and enables employees, codifies the knowledge base and increases boundary spanning (Dewett, 2003). However, it also bolsters individual creativity. For instance, Machrone (1994) highlighted how computers could help writers to be more creative by providing order and structure to their thoughts. This view was later formalised into the notion of “creativity support tools” (Shneiderman, 2007), denoting a wide set of technological artifacts facilitating the creative process.

We claim that, in the case of paradigm-shifting technologies, creativity enhancement goes beyond a circumscribed functional facilitation. Rather than being a tool, they generate an entirely new toolbox. This is a relevant and complex aspect of the relationship between new technologies and skills, which we aim to conceptualize and illustrate empirically.

2. THEORETICAL BACKGROUND

The relationship between technology and work has always been a vibrant research area. Several studies document a polarisation in the labour market: starting from the 1980s, middle-skill have lost ground to both high-skill and low-skill workers (Goos and Manning, 2007; Autor, Katz and Kearney, 2008; Goos, Manning and Salomons, 2009; Adermon and Gustavsson, 2015). Skill-biased technological change (Berman, Bound and Griliches, 1994; Autor, Katz and Krueger, 1998; Bresnahan, Brynjolfsson, and Hitt, 2002) and subsequently routine-biased technological change (Goos, Manning and Salomons, 2009, 2014) have been proposed to underlie the aforementioned evidence.

In analysing the technological impact on employment and wages, SBTC categorises workers based on their skill (high vs low), suggesting technology complements high-skill workers and supplants low-skill ones. Conversely, RBTC focuses on the nature of the task to be substituted (Autor, 2013). As the pioneering work of Autor, Levy and Murnane (2003) clarifies, the key determinant of substitutability is the extent to which a task is codifiable and repetitive, which is only indirectly related to the level of skill of the worker: technology substitutes for workers performing routine tasks (mostly middle-skill), and complements workers performing non-routine ones (typically at the extremes of the skill spectrum).

The taxonomy of tasks has evolved over time, from the simplified routine/non-routine dichotomy to Koorn, Leopold and Reijers’ complex reconceptualization (2018), identifying creative, adaptive, interactive, analytic, system supervision, routine cognitive, information processing and information exchange task categories.

The augmented granularity in task categories reflects the complexity of the technological landscape. Recent breakthroughs show peculiar characteristics in relation to work. Artificial intelligence has drawn considerable attention due to its potential to supplant labour in cognitive tasks, by overcoming Polanyi's paradox (Autor, 2014; Susskind, 2017). The combination of data availability, computational power, advanced robotics and sophisticated machine learning algorithms allows machines to learn by themselves how to carry out tasks with high analytical and/or motorial complexity, through statistical inference.

However, the domain suffers from a dearth of high-quality data (Frank et al., 2019). Empirical efforts concentrate on the effect of robots alone, with statistics aggregated by industry or country, while microeconomic understanding of the dynamics whereby advanced technologies complement or substitute for labour is still lacking (see Raj and Seamans, 2018 for a review). Even in task-based approaches, advanced technologies have been suggested to complement workers mainly by allowing them to focus on tasks that cannot be automated (Levy and Murnane, 2013). The idea that technology may act as a pure skill-amplifier within task categories is receiving less attention.

We advance the perspective that technologies comprising the fourth industrial revolution have a strong potential to complement workers directly in creative tasks. Given the link between creativity and organisational innovation (Amabile, 1983, 1988; Woodman, Sawyer and Griffin, 1993), the impact of technology on the creativity of employees carries high managerial relevance. Accordingly, it has been the object of studies at multiple levels of analysis.

On a general level, Dewett (2003) has elucidated how information technology engenders a chain of creativity-enhancing effects within organisations, by facilitating knowledge absorption and codification, and enabling employees to communicate more easily and frequently. A paradigmatic inter-employee communication enabler is the virtual team, with its peculiar set of dynamics and tools (Chamakiotis, Dekoninck and Panteli, 2013). Among such tools, electronic brainstorming has been shown to increase group creativity with respect to verbal brainstorming, well exemplifying the direct creativity-amplifying potential of technology in collaborative contexts (Siau, 1995). It is worth noting that indirect effects may also be present, as exemplified by suggestion system technologies, which enhance the creativity of employees by increasing their motivation (Fairbank and Williams, 2001).

As for the impact of technology on individual creativity, generic computerisation has the benefit of supporting the manipulation and storage of ideas, providing tutorials and databases, and offering insightful elaborations at various stages of the creative process (Lubart, 2005). More specifically, a variety of technological artifacts ranging from visualisation to simulation and mathematical manipulation tools have been conceptualised as "creativity support tools", an expression evoking their ability to bolster the creative potential of the user (Shneiderman, 2007). Interestingly, some of these tools aid the creative process also by granting users the ability to acquire knowledge in practice, which is conducive to creative output (Manucci, 2014). A well-known example of creativity support tool is Computer-Aided Design (Bonnardel and Zenasni, 2010).

While the idea that technology may support collective and individual creativity is well acknowledged, we argue that the impact of new digital technologies on creative tasks is more complex and pervasive. Disruptive technologies like additive manufacturing can hardly be regarded as mere creativity support tools, and should be framed within a more refined conceptual architecture.

3. OUR CONCEPTUAL FRAMEWORK

In the non-routine cognitive tasks' realm, we suggest that creative tasks deserve special attention. Creativity is commonly identified with the production of original and effective output (Runco and Jaeger, 2012), and the very notion of originality implies pushing the frontier further. As the space of possible outputs is virtually infinite, cognitive shortcuts like thinking and ideation heuristics play a significant role in exploring it. These are crucial peculiarities of creative tasks, requiring closer investigation.

Creativity is a multifaceted phenomenon. While divergent thinking leads to original ideas, originality is a necessary but not sufficient condition to achieve creativity (Runco and Acar, 2012): novelty evaluation through convergent thinking is a necessary step after novelty generation (Cropley, 2006). Furthermore, these thought processes do not operate in isolation. According to Csikszentmihalyi (1997), creativity derives from a complex interaction between the individual, the domain and the field. A popular taxonomy of the individual components of creativity recognises domain-relevant skills (e.g. technical skills), creativity-relevant skills (e.g. appropriate cognitive style) and task motivation (Amabile, 1983). These declinations of individual skills interact with the domain, which establishes the rules of the game where creation takes place, defining symbols, notions, procedures, techniques and heuristics. Finally, the field denotes the community that recognises and validates the output of creative activity. While Csikszentmihalyi's original focus (1997) was on "creativity with a capital C", denoting the act of revolutionizing domains themselves, its constructs remain useful also for the wider notion hereby adopted (i.e. Runco and Jaeger, 2012), providing a clear positioning for technology in the domain category. In turn, additive manufacturing (AM) provides a clear illustration of the creativity-enhancing potential of paradigm-shifting technologies.

AM denotes the production technique of recreating a whole through layer-by-layer overlapping of material, by tridimensionally printing it from a digital model. Rapid prototyping and higher freedom in design are among its numerous benefits (Berman, 2012; Attaran, 2017). Final products require several iterations of prototypes, to test for structural and geometrical features. By their very nature, prototypes do not generate the economies of scale on which traditional manufacturing thrives. Thus, additive manufacturing is a much faster alternative, resulting in reduced time-to-market. Moreover, AM enables the reproduction of complex product shapes and geometries that would be difficult or impossible to reproduce with other methods, bringing both functional and aesthetic benefits.

In manufacturing industries where aesthetics matter, design is a crucial value creating activity. In this context, designers use their visualisation, imagination and drawing skills (individual) to create aesthetically appealing output, with a well-defined set of tools and following precise ideation heuristics (domain), conforming to market-driven and socio-cultural criteria (field). By releasing design constraints, AM determines a domain extension. Intricated combinations of twists and cavities represent additional tools in designers' arsenal, leading to the emergence of jewels and accessories with shapes that used to be unthinkable. Furthermore, printing entire products ex novo is not the only possibility. The range of creative opportunities gets even larger by integrating AM with traditional manufacturing. This practice is widely adopted in the hearing aid industry, where external shells are 3D printed and internal electronic components are standardised.

Within the domain, heuristics play a decisive role in determining the extent to which individual skills benefit from toolbox expansions. The role of heuristics in facilitating the exploration of the space of possible designs is well acknowledged (Yilmaz et al., 2011; Yilmaz and Seifert, 2011; Daly et al., 2012). They constitute cognitive shortcuts, automatisms, and simplified avenues to design solutions. While they are typically beneficial to creative efforts, they can become serious impediments to exploiting the full benefits of a domain extension. That is because heuristics are rooted in consolidated bodies of knowledge and practice. As Lenat (1980) argues: "As new domains of knowledge emerge and evolve, new heuristics are needed. A field may change by the introduction of some new device, theory, technique. paradigm, or observable phenomenon: each time it does so, the corpus of heuristics useful for dealing with that field may also change". Individuals may tend to continue using the outdated heuristics even in the presence of novel tools, simply because their mind is hardwired to do so. For example, in the case of traditional manufacturing, optimised for modularisation, "simple is better" is a very powerful heuristic, which is in conflict with the "complexity for free" motto of AM.

Given these premises, we formalise the complementarity channel that links AM to skill augmentation in the following conceptual framework.

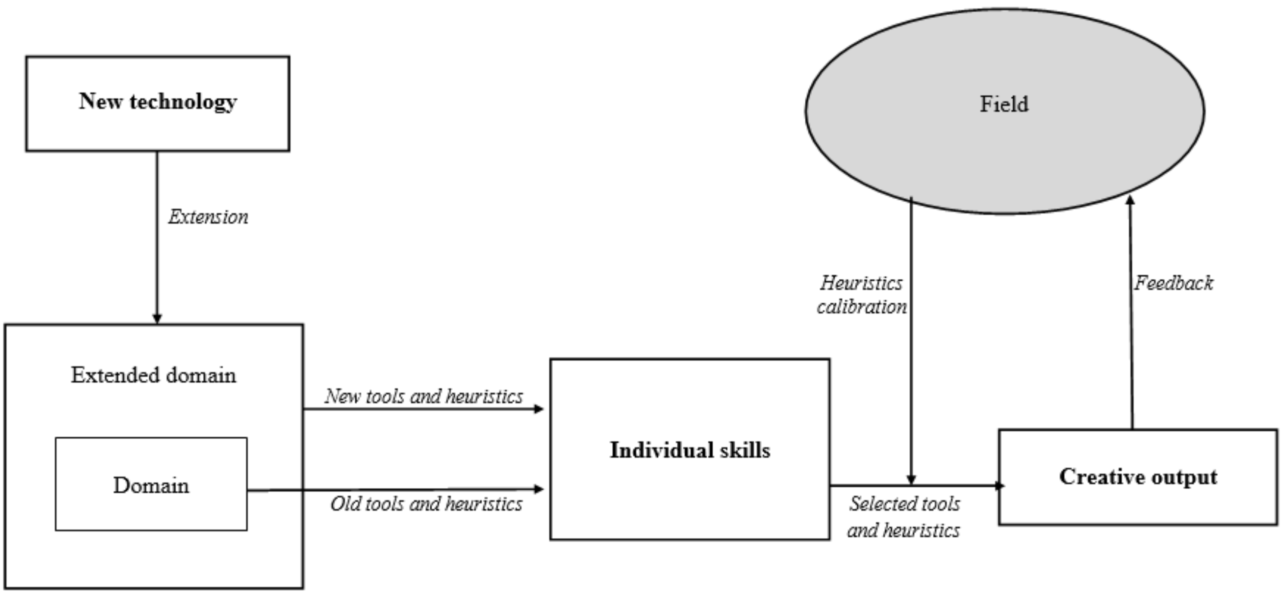

Figure 1 – a conceptual model of creativity enhancement

AM extends the domain of tools that designers have at their disposal, by accelerating prototyping and removing design constraints. The former reduces the cost of experimentation, incentivising creativity, while the latter extends the space of possible designs. Accordingly, employees can blend their domain-relevant and cognitive-relevant skills with any combination of the old or the new tools, and explore the design space through a variety of heuristics, pertaining either to the original or the enlarged domain. As heuristics tend to be persistent, designers are likely to stick with the old heuristics at first, with only a timid exploitation of the new creative potential. Nevertheless, with continued practice, they will progressively move towards the extended domain's heuristics, engendering a self-reinforcing process of creativity upgrading.

At the centre of this process lies the field. However timid the initial use of the extended pool of tools, the field will recognize it from the creative output. Then, assuming an improvement, it will reward it. Rewards, in the form of implicit and explicit feedbacks on the creative output, will dynamically push designers towards the new paradigm.

4. THE CASE OF LUXOTTICA

4.1 METHODOLOGY

Our conceptual effort suggests that AM extends the domain of the design creative task. We expect this effect to emerge most vividly in a context where product excellence, creativity and attention to detail are essential. Thus, we consider the high-end eyewear sector, within which AM represents a highly relevant technological paradigm.
Luxottica is a global leader in the sector, with 9 billion euros sales, 82000 employees worldwide and a distribution network spanning 150 countries. Brand image maintenance and international competition maximise Luxottica's incentives to adopt the latest technological solutions to keep its premier position in the market. Additionally, Luxottica has an idiosyncratic drive for innovation. Innovative thinking is well-rooted in the company's heritage, with its R&D team pioneering many breakthroughs in frames and sun lenses through intensive experimentation, leading to more than 1000 utility, design and technology patents worldwide. The company is explicitly committed to the digital transformation, heavily investing in industry 4.0 technologies like 3D printing, robotics and big data analytics. Furthermore, Luxottica strives for excellence in the human resource department, placing considerable emphasis on the value of craftmanship and creativity. These features constitute the ideal picture to inquire into the interaction between AM and creative labour.
As a first step, we searched for all official documents containing relevant information on the topic. We downloaded annual financial reports reviews from 2003 to 2018, and searched for press releases and public interviews on Luxottica's approach to innovation, AM and human resource management. We stored official documents in a dedicated database, screened them for relevant content and triangulated them as an initial check for internal consistency, with no anomaly revealed.
Subsequently, we complemented this material by interviewing the global R&D director and the frames R&D manager of the company. Building on our conceptual framework, we adopted a semi-structured interviewing scheme, in order to maintain thematic relevance while allowing interviewees to stress the most important points autonomously. Whenever possible, the information was triangulated with the aforementioned material, to ensure reliability.
Interviews were transcribed verbatim and added to the case database. Finally, coding enabled us to extract essential units of meaning from the text, and prepare them for aggregation into categories, with a view to refining our framework's concepts. For this purpose, we adopted a mix of in vivo coding and constructed coding (Saldaña, 2015).

4.2 RESULTS

The empirical findings corroborate our conceptual framework. In the following paragraphs, for each block of the framework, we summarise the emerging insights.

4.2.1 NEW TECHNOLOGY

Luxottica has confirmed the adoption and strategic relevance of AM. They employ proprietary 3D printers and have increased their use of the technology over time. The main use is prototyping, but 3D printing is also used for tooling and final product manufacturing.

4.2.2 CREATIVE OUTPUT

The value of a high-end pair of glasses is multifactorial. Excellent components must be crafted together in appealing, functional and aspirational architectures. While 3D printing is essential in the design process of all glasses for prototyping, tooling and refinement, 3D printed final products are typically destined to boutiques in limited editions.

4.2.3 DOMAIN

In this crucial block, most expectations have been met. The importance of AM in accelerating prototyping has been clarified and expanded upon. Rapid prototyping is highly beneficial in the design phase, where it accelerates the verification of shapes, geometries and functional requirements. To this end, quite interestingly, the benefits of 3D printed tools have also been stressed. Different prototypes require different sets of specific tools. The possibility to rapidly print both prototypes and tools as the need arises facilitates design iterations, encouraging experimentation and creativity.

3D printing also extends the set of possible designs. In particular, it allows designers to play with internal cavities and transparencies. However, as expected, constraining heuristics related to traditional manufacturing have been reported to limit the potential creativity increase.

Another aspect of relevance is the domain's dynamic expansion. The set of tools, notions and procedures on which creativity in the eyewear business is based does not expand abruptly. Conversely, it seems to follow a smooth trend, grounded on the convergence of several technologies. Some of them are part of industry 4.0, others are not. Traditional manufacturing itself is regarded as complementary to additive manufacturing. This remarks the value of creatively integrating the strengths of additive and subtractive techniques, and exploiting complementary technologies such as CAD and 3D scanning.

4.2.4 Individual skills

The high-end eyewear sector is product-centric. Thus, the quality of the workforce is of paramount importance, both in terms of general aptitudes and specific competences. The competitive advantage of the firm is firmly grounded on the creativity, open-mindedness and drive for excellence of its employees. Thus, Luxottica strives to source and nurture individual skills.

Within Amabile's taxonomy (1983), Luxottica actively sources for creativity-relevant skills, like a high level of education, an open mindset and a positive psychological inclination, while it prefers to develop domain-relevant skills in-house, implementing ad-hoc training sessions and other intra-firm knowledge diffusion mechanisms. This reflects the scarce fungibility of the qualities required to produce glasses up to Luxottica's standards. Indeed, even though the transferability of designs is among the strengths of additive manufacturing, Luxottica does not engage in the remote hiring of employees or remote collaborations. Creative leadership seems to be indispensable and incompatible with remote collaborations.

4.2.5 Field

Csikszentmihalyi refers to the field as the community that gives creative output meaning and validation (1997). In the case of eyeglasses, customers are the final judges. However, employees do not relate directly to the market, but act within an organisational context characterised by a set of assumptions, norms, rules and reward mechanisms. In this sense, the firm acts as a mediator, incorporating market signals into its path-dependent cultural architecture.

Luxottica seems to exert a solid form of creative leadership, by actively promoting open-mindedness and urging employees to think outside the box. This process originates from top-down initiatives like dedicated training sessions to accelerate the renewal of heuristics, and diffuses through standard practices like the sharing of daily activities, informal chats and other socialisation mechanisms, fostered also by ad-hoc policies like rotational transfers of designers to different locations. This is perfectly consistent with the stream of literature in creative leadership highlighting the role of leaders as facilitators of the creative process (Mainemelis, Kark and Epitropaki, 2015).

5. DISCUSSION AND CONCLUSION

Consensus has been reached on the tendency by technology to substitute for middle-skill workers and complement high-skill and low-skill workers, the theoretical rationale being the easier automatability of routine tasks (Autor, Levy and Murnane, 2003; Autor, Katz and Kearney 2006). Nowadays, the debate on the future of work is as intense as ever, due to the emergence of disruptive automation and digitalisation technologies, popularised as industry 4.0. Some of these technologies, particularly artificial intelligence and advanced robotics, have spread concerns of massive unemployment, due to their potential to automate even the most complex cognitive and interactive tasks (Frey and Osborne, 2017). These concerns have relatively overshadowed the other side of the coin, namely complementarity. Even in task-based approaches, advanced technologies have been suggested to complement workers mainly by allowing them to focus on tasks that cannot be automated (Levy and Murnane, 2013). The idea that technology may act as a pure skill-amplifier within specific tasks has received less attention.

Focusing on additive manufacturing, we have highlighted the alternative role of technology as a pure skill amplifier, through the creativity channel. Drawing insights from creativity theory (Amabile, 1983; Csikszentmihalyi, 1997; Cropley, 2006; Runco and Acar, 2012) we have shown how advanced technologies may extend a creative task's domain, leading to novel combinations of individual skills and tools, and boosting creative output. In the additive manufacturing case, the domain extension concerns the space of possible designs and experimentations, enabled by the relaxation of design constraints and the acceleration of prototyping. Furthermore, we have underlined the role of heuristics in the elaboration of creative solutions, and advanced that the persistence of old heuristics in the new domain (Lenat, 1980) may slow down the creative potential augmentation.

The Luxottica case study confirms that AM allows high-end eyewear producers to be faster and more creative in introducing new models. It also underscores the persistence of heuristics inherent in the traditional manufacturing mindset, and their role in limiting designers' creative potential. Moreover, it highlights the importance of creative leadership in accelerating the transition to the new manufacturing mindset, revealing a new declination of the supporting role of creative leaders (Mainemelis, Kark and Epitropaki, 2015).

With the present work, we aim to contribute to the debate on the relationship between skills and technology in the digital era, by offering an alternative view. While industry 4.0 technologies are likely to require new skills, those technologies themselves also contribute to amplifying skills. Our framework emerged from a combination of deduction and induction from the AM case, but we believe it is suitable for generalization to other industry 4.0 technologies (e.g. artificial intelligence, which is mostly studied for its substitutive effect on labour).

As a conceptual paper with a single empirical illustration, this work shows that technologically-driven creativity enhancement is theoretically solid and, in some cases, empirically relevant. It also elucidates the dynamics of this phenomenon in the additive manufacturing case. Measuring, comparing and contrasting the AM case with other technologies may be valuable research endeavours. Hence, we encourage further research in this direction, to develop more extensive insights into the creativity-amplifying effect of advanced technologies.

REFERENCES

Adermon, A., & Gustavsson, M. (2015). Job Polarisation and Task-Biased Technological Change: Evidence from Sweden, 1975–2005. The Scandinavian Journal of Economics, 117(3), 878-917.

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualisation. Journal of Personality and Social Psychology, 45(2), 357.

Amabile, T. M. (1988). A model of creativity and innovation in organizations. Research in Organizational Behavior, 10(1), 123-167.

Arntz, M., Gregory, T., & Zierahn, U. (2017). Revisiting the risk of automation. Economics Letters, 159, 157-160.

Attaran, M. (2017). The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing. Business Horizons, 60(5), 677-688.

Autor, D. (2014). Polanyi's paradox and the shape of employment growth (Vol. 20485). Cambridge, MA: National Bureau of Economic Research, Working Paper 20485.

Autor, D. H. (2013). The task-based approach to labour markets: an overview. Journal for Labour Market Research, ISSN, 2510-5027.

Autor, D. H., Katz, L. F., & Kearney, M. S. (2006). The polarisation of the US labour market. The American Economic Review, 96(2), 189-194.

Autor, D. H., Katz, L. F., & Kearney, M. S. (2008). Trends in US wage inequality: Revising the revisionists. The Review of Economics and Statistics, 90(2), 300-323.

Autor, D. H., Katz, L. F., & Krueger, A. B. (1998). Computing inequality: have computers changed the labour market?. The Quarterly Journal of Economics, 113(4), 1169-1213.

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The skill content of recent technological change: An empirical exploration. The Quarterly Journal of Economics, 118(4), 1279-1333.

Berman, B. (2012). 3-D printing: The new industrial revolution. Business Horizons, 55(2), 155-162.

Berman, E., Bound, J., & Griliches, Z. (1994). Changes in the demand for skilled labour within US manufacturing: evidence from the annual survey of manufactures. The Quarterly Journal of Economics, 109(2), 367-397.

Bonnardel, N., & Zenasni, F. (2010). The impact of technology on creativity in design: an enhancement?. Creativity and Innovation Management, 19(2), 180-191.

Botha, A. P. (2018). Rapidly arriving futures: future readiness for Industry 4.0. South African Journal of Industrial Engineering, 29(3), 148-160.

Bresnahan, T. F., Brynjolfsson, E., & Hitt, L. M. (2002). Information technology, workplace organisation, and the demand for skilled labour: Firm-level evidence. The Quarterly Journal of Economics, 117(1), 339-376.

Brynjolfsson, E., & McAfee, A. (2011). Race against the machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy. Digital Frontier Press Lexington.

Chamakiotis, P., Dekoninck, E. A., & Panteli, N. (2013). Factors influencing creativity in virtual design teams: An interplay between technology, teams and individuals. Creativity and Innovation Management, 22(3), 265-279.

Cropley, A. (2006). In praise of convergent thinking. Creativity Research Journal, 18(3), 391-404.

Csikszentmihalyi, M. (1997). Flow and the psychology of discovery and invention. Harper Perennial, New York, 39.

Cummings, A., & Oldham, G. R. (1997). Enhancing creativity: Managing work contexts for the high potential employee. California Management Review, 40(1), 22-38.

Daly, S. R., Yilmaz, S., Christian, J. L., Seifert, C. M., & Gonzalez, R. (2012). Design heuristics in engineering concept generation. Journal of Engineering Education, 101(4), 601-629.

Dewett, T. (2003). Understanding the relationship between information technology and creativity in organisations. Creativity Research Journal, 15(2-3), 167-182.

Fairbank, J. F., & Williams, S. D. (2001). Motivating creativity and enhancing innovation through employee suggestion system technology. Creativity and Innovation Management, 10(2), 68-74.

Frank, M. R., Autor, D., Bessen, J. E., Brynjolfsson, E., Cebrian, M., Deming, D. J., ... & Wang, D. (2019). Toward understanding the impact of artificial intelligence on labour. Proceedings of the National Academy of Sciences, 116(14), 6531-6539.

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation?. Technological Forecasting and Social Change, 114, 254-280.

Galaske, N., Arndt, A., Friedrich, H., Bettenhausen, K. D., & Anderl, R. (2017). Workforce management 4.0-assessment of human factors readiness towards digital manufacturing. In International Conference on Applied Human Factors and Ergonomics (pp. 106-115). Springer, Cham.

Goos, M., & Manning, A. (2007). Lousy and lovely jobs: The rising polarisation of work in Britain. The Review of Economics and Statistics, 89(1), 118-133.

Goos, M., Manning, A., & Salomons, A. (2009). Job polarisation in Europe. American Economic Review, 99(2), 58-63.

Goos, M., Manning, A., & Salomons, A. (2014). Explaining job polarisation: Routine-biased technological change and offshoring. American Economic Review, 104(8), 2509-26.

Koorn, J. J., Leopold, H., & Reijers, H. A. (2018). A task framework for predicting the effects of automation. In 26th European Conference on Information Systems, ECIS 2018.

Lenat, D. B. (1980). The nature of heuristics. Stanford University.

Levy, F., & Murnane, R. J. (2013). Dancing with robots: Human skills for computerized work. Washington, DC: Third Way NEXT, 5-35.

Lubart, T. (2005). How can computers be partners in the creative process: classification and commentary on the special issue. International Journal of Human-Computer Studies, 63(4-5), 365-369.

Machrone, B. (1994). Computers and creativity. PC Magazine, 13(21), 87-92.

Mainemelis, C., Kark, R., & Epitropaki, O. (2015). Creative leadership: A multi-context conceptualization. Academy of Management Annals, 9(1), 393-482.

Mannucci, P. V. (2014). Drawing Mickey Mouse and Animating Nemo: How the Use of Technological Tools Affects Creativity. In Academy of Management Proceedings (Vol. 2014, No. 1, p. 11500). Briarcliff Manor, NY 10510: Academy of Management.

Pajarinen, M., & Rouvinen, P. (2014). Computerisation threatens one third of Finnish employment. Etla Brief, 22(13.1).

Raj, M., & Seamans, R. (2018). AI, labour, productivity, and the need for firm-level data. In The Economics of Artificial Intelligence: An Agenda. University of Chicago Press.

Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. Creativity Research Journal, 24(1), 66-75.

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. Creativity Research Journal, 24(1), 92-96.

Saldaña, J. (2015). The coding manual for qualitative researchers. Sage.

Shneiderman, B. (2007). Creativity support tools: Accelerating discovery and innovation. Communications of the ACM, 50(12), 20-32.

Siau, K. L. (1995). Group creativity and technology. The Journal of Creative Behavior, 29(3), 201-216.

Susskind, D. (2017). Re-Thinking the Capabilities of Machines in Economics. Department of Economics Discussion Paper Series, University of Oxford.

Woodman, R. W., Sawyer, J. E., & Griffin, R. W. (1993). Toward a theory of organizational creativity. Academy of Management Review, 18(2), 293-321.

Yilmaz, S., & Seifert, C. M. (2011). Creativity through design heuristics: A case study of expert product design. Design Studies, 32(4), 384-415.

Yilmaz, S., Daly, S. R., Seifert, C. M., & Gonzalez, R. (2011). A comparison of cognitive heuristics use between engineers and industrial designers. In Design Computing and Cognition'10 (pp. 3-22). Springer, Dordrecht.