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Edited by

Paul Griffiths and Mitt Nowshade Kabir

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The Effects of Artificial Intelligence, Robotics, and Industry 4.0 Technologies. Insights from the Healthcare Sector

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Abstract: Artificial Intelligence (AI) is listed as the number one strategic technology, enabling new ways of creating, delivering and capturing value among stakeholders and constituting a major source of innovation with a potential contribution of $15 trillion to the world economy by 2030. The rapid progress in this highly disruptive technology calls for a better understanding of its growth and potential impacts on individual lives, society, and the global setting. AI and robotics are already transforming our lives from self-driving cars and drones to virtual assistants and translation software solutions. Healthcare is one of the sectors that are most affected by new Industry 4.0 technologies in general and AI and robotics in particular. The paper aims to investigate the future of healthcare by analysing the case of Nucleode, an innovative company based in the north-east of Italy. Nucleode aims to provide new technologies responding to various needs, particularly regarding hospital management. Its mission is "taking healthcare to the future." Analysing some of Nucleode's case studies, the paper aims to discuss the application of technologies such as mixed reality, cloud computing, AI and robotics in healthcare, showing how new technologies can change the scenario, also considering intellectual capital management.

Keywords: Strategy Innovation, Healthcare, Artificial intelligence, Intellectual Capital, Surgery

1. Introduction and research questions

In the nineties, the concepts of "innovation" and "Strategy" have attracted scholar and practitioners fostering a growing production of scientific papers in the fields, representing those concepts as two different aspects of the same coin. On the one side strategy has been focused on the way to compete within a specific market sector and to define the field of action of the organization to achieve its goals. On the other side, the literature on innovation has focused its attention on the product and process innovation (Schlegelmilch *et al.*, 2003). We can state how the literature on strategy studies the overall aims of the organization, while, on the contrary, innovation has been seen as a tool to achieve organizational goals.

From the nineties, the concepts of innovation and strategy have started to become more linked, thanks to the introduction of the idea of strategic innovation (Schlegelmilch *et al.*, 2003). Strategic innovation is the process of developing or reinventing the organizational strategy, i.e. Structural Intellectual Capital. Organizations can achieve strategic innovation thought the development of new products or services, presented or combined in an original way, to create a radically new experience for clients/end users, involving them also at an emotional level. Additionally, strategic innovation can also arise from the reconfiguration of the sector's value chain to change the rules of the game - exploiting, for example, the possibilities offered by new technologies to enhance the distinctive competencies of the company (Buaron, 1981).

According to the Resource Based View theory, companies need to have access to distinctive resources to support Strategic Innovation and Intellectual capital (IC) has been considered as one the most important resource. Since its first development IC is defined as the set of intangible assets that the firm owns or has access to (Edvinsson and Malone, 1997). Traditionally, IC has been divided into three pillars: *human capital (HC)*, which represents the employees' knowledge, skills and experience (Abeysekera and Guthrie, 2004; Dal Mas, 2019; Edvinsson, 2000; Massaro *et al.*, 2018); *structural capital (SC)* which is about the organization's codified knowledge, databases, and culture (Bontis, 1998; Massaro *et al.*, 2017); and *relational capital (RC)* which represents the knowledge embodied in the networks of internal and external relationships that the company manages (Dal Mas, Paoloni, *et al.*, 2019; Massaro *et al.*, 2014; Peng and Bewley, 2010; Secundo *et al.*, 2018). IC has several distinctions. One of them is the Intangibles. Another is more dynamic as Future Earnings Capabilities.

According to Prof. Edvinsson since 1990s the dominant investment flow, both in the USA and Sweden, have gone into intangibles, such as R&D, Intellectual Property Rights, education and competencies, IT software and the Internet (Edvinsson, 2000, 2002), and this is also reflected by companies' stock value. A Galaxy of Intangible Value emerge, that might be structure by the Value Scheme of IC. Edvinsson defined the phases of the pattern of market capitalization growth and IC global growth, following the experience of Skandia's market value growth. Each phase as defined by Edvinsson resulted, for the Swedish insurance company Skandia, in a stock market appreciation growth, based on an increased transparency, but also on new expectations by investors from the future value creation coming from the investment on intangible assets. The following figure show the market capitalization value over time.

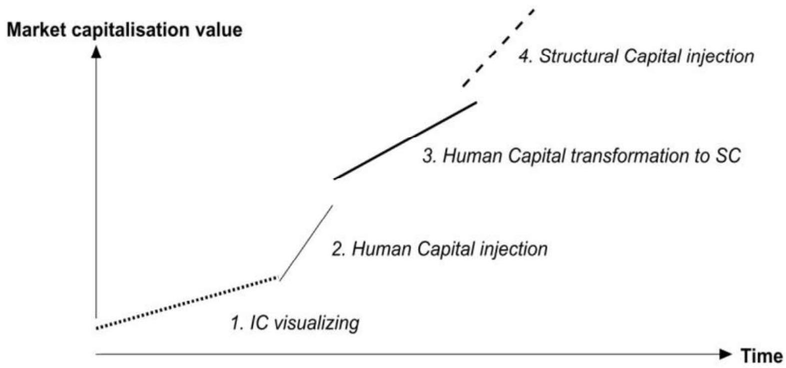

Figure 1: Market Capitalization Value pattern over time (source: Edvinsson, 2000, pag.15)

The first phase is about the visualization of intangibles from a reporting perspective. The second phase is about the human capital injection, adding skills and competencies, also in a knowledge management perspective (knowledge sharing, IT-based knowledge systems, ...). The third phase concerns the systematic transformation of human capital into structural capital as a multiplier, which leads to more sustainable earnings potential for the organization. The fourth phase requires an external structural capital injection. The effect of the fourth phase can be defined "as a "turbo effect" on the IC multiplier by combining different types of structural capital constellations for co-creation of new opportunities" (Edvinsson, 2000). These phases of IC growth have the power of gradually increasing the value creation potential of organizations.

Coming to new technologies, according to Gartner's 2018 technology trend survey, Artificial Intelligence (AI) is listed as the number one strategic technology. AI enables new ways of creating, delivering and capturing value among stakeholders (Ransbotham and Mitra, 2010), constituting a major source of innovation (Russel and Norvig, 2010), with a potential contribution of $15 trillion to the world economy by 2030 (Rao *et al.*, 2017).

The rapid progress in this highly disruptive technology calls for a better understanding of its growth and potential impacts on individual lives, society, and the global setting. Business leaders must adopt a mindset and new practices that accept and embrace this change, translating technological possibilities into business value for customers, partners and society (Biloslavo *et al.*, 2017; Teece, 2010) AI and robotics are already transforming our lives (Schwab, 2017): from self-driving cars and drones to virtual assistants and translation software solutions. The growing development of new technologies has substantial impact on IC and therefore on strategy innovation (Bagnoli *et al.*, 2018, 2019; Nielsen *et al.*, 2018). Healthcare in general and surgery, in particular, are among the sectors which are most affected by new technologies (Christensen *et al.*, 2000; Iacopino *et al.*, 2018; Lucas, 2015; Mascia and Di Vincenzo, 2011; Snowdon *et al.*, 2015). Starting from this premise, our chapter aims to discuss the future of surgeons' work, considering the impact of new technologies in healthcare.

2. Research method

To investigate our research goal, we employ a case study approach (Yin, 2009). According to Bolton and Stolcis (2003, p. 628) practitioners have “preference for case studies and research derived from practice experience” and therefore the use of more qualitative approaches could help to speed the application of research studies among practitioners (Dal Mas, Massaro, *et al.*, 2019; Massaro *et al.*, 2016). To ensure transparency, we tried to be as rigorous as possible in our analysis (Massaro *et al.*, 2019).

The main case study analysed in our paper is about the Kiron project, carried on by Nucleode Srl, an innovative start-up company in the field of technology and healthcare based in Gorizia, Italy. We chose to analyse the case of Nucleode since it is an innovative company working in one of the sectors which are most affected by a digital transformation swift. Moreover, Nucleode can be defined as an intense- knowledge company, since it relies on its Intellectual Capital to reach its success. Its Human Capital is one of the key resources of the organization, with high-skilled professionals of different fields (Medicine, Engineering, IT, Graphic Design and Communications). The company relies on its Structural Capital, which is the core of its product development. At the same time, the organization uses the top technologies. Relational Capital is also a relevant resource.

Nucleode works closely with hospitals, private clinics, universities, and doctors, to ensure the best connections and trials to the end users of its products. The context in which Nucleode works makes it ideal for studying the impact of new digital technologies on healthcare. Data acquisition was made involving several people for the company, and all materials coming out from the interviews were double checked with the company’s CEO.

3. The Company, Project idea & vision

Nucleode Srl[1] is an innovative start-up based in Gorizia, in the north-east of Italy, active in the field of new technologies related to healthcare, founded in March 2017. The vision of Nucleode can be summarized as "better healthcare for everyone." The mission of the company is to drive the healthcare environment into the future, helping physicians, researchers, and patients to take advantage of the last technology innovations, in particular using Industry 4.0 technologies such as Cloud Computing, AI, Robotics, Blockchain, and Mixed Reality.

The project "Kiron"[2] (Dal Mas, Piccolo, *et al.*, 2019) aims at improving the current navigation systems, offering surgeons more sophisticated and thus more useful information bringing Augmented Reality and Cloud Computing technologies to the operating room. The goal is to be able to visualize for the first time in a 3D space both in the planning phase of the intervention and during surgery a brain with some pathology such as a tumour, a vascular or anatomical malformation, etc.

Image-guided neurosurgeries systems (IGNS), so-called neuronavigation systems, were introduced into neurosurgery in the late 1980s and early 1990s. In IGNS, surgical tools are tracked in real time and displayed on a navigation system. Traditional systems have several shortcomings in terms of registration, visualization and surgeon–computer interaction: ergonomics of such devices are still not optimal, technical and user-experience choices are not always adequate in an increasingly specialized context of use (Drouin *et al.*, 2017).

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[1] Company website: https://nucleode.com/

[2] Project website: https://kiron.nucleode.com

The most popular type of neuronavigation system is the optical system (Enchev, 2009). One of the weaknesses of this optical system is that physician is forced to look away from the surgical area to watch the navigation display considering that the navigation monitors are located away from the lens tubes of the microscope and monitors of the neuroendoscope. Then, the operator is required to transfer the information from the "virtual" environment of the navigation system to the real surgical field.

Kiron aims to give a new dimension to neuronavigation, projecting directly on the patient in holographic form all the anatomical details that may be needed during the operation, without the need to look away from the operating field. The technology allows the neurosurgeon an immersive experience, allowing to observe the objects of interest directly within the patient and decreasing the surgical times, as it is no longer necessary to look away to check the exact position of the neuronavigation on the monitor. A further advantage is the easier and more precise pre-operative planning, carried out directly on the patient. The possibility of directly visualizing the ventricular system within the patient using holographic technology makes the intervention easier, minimizing the risks of failure and overcoming anatomical limits of the individual patient, all taking advantage of cheap and routine radiological examinations, such as the brain scan.

Surgical planning for a brain tumour starts from data acquired from high-field magnetic resonances to create a 1:1 scale 3D model that faithfully reproduces the patient's brain, both with regard to the cortical surface and the deep structures, including vascularization. DTI and tractography data, as well as data acquired with functional brain MRI, are added to the anatomical data, providing all the information useful for the neurosurgeon to conduct the operation within a single three-dimensional model. Those steps are done in a secure cloud platform with an integrated 3D viewer with advanced features, then securely transferred to the holographic device for usage before and during surgery.

Before surgery, Kiron allows improving the planning and pre-operative preparation by the surgeons, thanks to its ability to accelerate the acquisition of specific 3D anatomic knowledge, that generally comes from the neurosurgeon's past experience and abilities. The quality of data that can be gathered in this pre-operative phase is relevant for the success of the operation. Augmented reality planning generally contributes to reducing the surgeon's guesswork and enables surgical procedures to be tailored for specific anatomical considerations. Usually, an unpredictable variety of vessels, structural shapes, and cranial nerves obstruct the surgical route, which makes detailed planning mandatory for determining the best surgical approach for each patient.

The use of Kiron during the operation provides the physician with several data and information on the lesion and on the patient directly on the vision field, ensuring in this way a clear view of the surgical area during all the operating time, looking directly on the operating field and not, as it usually happens, on the monitor.

4. The impact of digital transformation and intellectual capital management in surgery

The case of Kiron can be seen as an innovation in healthcare. Indeed, the use of technologies like Kiron can lead to several improvements in surgery:

- more accuracy in planning the surgery, given the ability to forecast all anatomical details, in terms of needs during the operation and the predicted time;
- more efficiency for the surgeon, who can concentrate on the operating field without the need of looking away;
- more data that can be gathered before and after the surgery that can enhance the surgeon's knowledge, as well as the general scientific understanding.

What is currently happening in surgery, with the introduction of new digital innovations such as Kiron, can follow the framework of Edvinsson.

As explained above, Edvinsson analysed the global growth curve of IC, based on the global scenario and his personal situation as the world's first director of intellectual capital at Skandia AFS (Edvinsson, 2000). Edvinsson recognizes several phases which resulted in stock market appreciation shifts. After the first phase of visualization of the intangibles, phase two concerns a human capital injection, followed up by a third phase in which human capital is transformed into structural capital as a multiplier. The fourth phase is about an external infusion of structural capital.

Projects like Kiron or the use of robots or AI in surgery were conceived starting from the needs and knowledge of the current stage of human capital, both from an engineering/technological side as well as from a medical perspective. The development of such technologies, from the initial concept to the first project, prototype, and trial, has been possible merging a variety of different actors: both human (doctors, engineers, graphic designers, ...) as well as technical (software and solutions available on the market). The relational capital outside the developer with external doctors and professors, is usually crucial to ensure the clinal trial, the measurements, and the validation of the final results.

In this sense, we may see new technologies in surgery as the transformation of human capital into a structural capital tool. Once innovative tools as Kiron are included as external devices in healthcare organizations, they require further human capital injections, in terms of new knowledge needed.

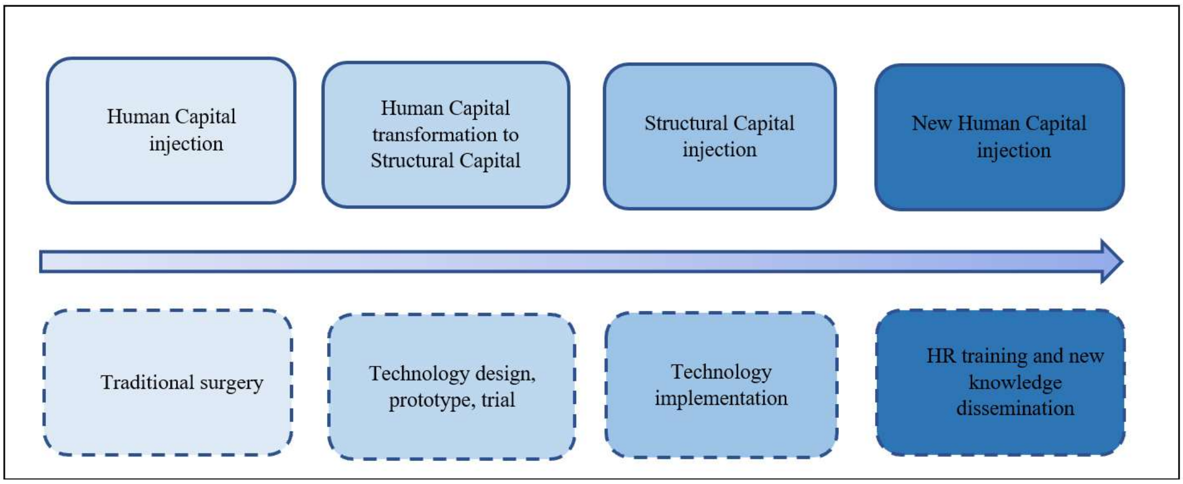

Figure 2: IC and surgery over time

The role of the surgeon changes for good. The support of the innovative tool helps to read the clinical situation prior to the surgery. A massive amount of data is collected, so most of the initial guesswork of the physician is replaced by a clearer picture of the clinical condition. Data allows forecasting the time and the resources needed for the operation more accurately. Unpredicted situations will occur less frequently. The surgery itself will end up more comfortable for the surgeon, in the case of Kiron given the ability to look directly at the affected area, and not on other screens. After the surgery, more data can be collected and analysed. In this sense, the knowledge required by the surgeon will turn more on the experience/guesswork side to the ability to take advantage of data, not only in the single patient perspective but on the whole medical science.

In our framework, every phase led to an increase in the market capitalization value of the organizations. In the healthcare sector, we can state how each phase leads to a broader concept of value for the patient/end user.

The innovation allows the patient to get a more accurate pre-operational plan and surgery, less linked to the physician's experience and ability. This will lead to a better chance of getting the expected clinical result. The better picture of the initial operational plan can lead to better management of the required resources, both human (e.g., physicians from other hospital departments), as well as technical (correct use and booking of the operating room). This will bring a better cost/benefit value for the healthcare organization in terms of efficacy, efficiency, and money spent, with an impact on the final outcome (Dal Mas, Massaro, *et al.*, 2019). The extra data collected before, during, and after the surgery can then lead to a better understanding of surgery as a science. Through the dissemination of results with scientific publications and presentation to medical congresses data can be useful to any surgeon dealing with the same situations.

The same concepts also apply to the application of AI and robotics in general surgery, where the use of robots (like the da Vinci® System SI, X, XI, and SP) has been present for years now.
According to the literature, AI will undoubtedly affect the evolution of future surgical robots. At present, robots allow better visualization of the operative field, movements with articulating tools, and the elimination of vibration. However, the entire decision-making process is always the responsibility of the surgeon (Aruni *et*

al., 2018). Nowadays, robots that can independently carry out parts of surgical operations using AI technology already exist. Some robots can, for example, perform intestinal anastomoses more precisely and faster than experienced surgeons (Shademan *et al.*, 2016). Again, the use of AI in surgery can lead to the saving of time, a decrease in medical errors, and better surgical outcomes both for the patient as well as for the hospital or clinic adopting the technology (Köse *et al.*, 2018). One of the main reasons that are limiting the spread of robotic systems with AI is related to the legal medical issues linked to the responsibility of the surgical procedure (Atabekov and Yastrebov, 2018). We do expect these problems to be solved in the upcoming years.

If the intellectual capital in healthcare can embrace AI we may see a revolutionary outcome that transfers business models and collaboration at scale. Significant opportunities exist to support staff, patients and the wider community to improve their health and wellbeing.

According to the British Medical Journal (Limb, 2016) by 2030 we will face a shortfall of 18 million medical professionals worldwide. Training and development of medical professionals can be developed using this technology to scale how we train the staff of the future. Virtual Surgeon Shafi Ahmed is pioneering medical training and has been using VR and AI to support students worldwide.

Can AI be the technology that supports and enables diminishing resources? How can AI support? The key is time to treat, improving the outcomes for our patients while delivering value for money. Surgery is one area that will bring improved outcomes for patients, clinicians and managers. AI brings opportunities to enhance and support decision making while giving time to treat to clinicians. Managers can use the technology to resource match and forward plan their services using data. Can patients benefit from this technology? Will they trust and embrace the opportunities? Demand is rising and the need will drive the innovation to change.

The value created will be significant and can be multiplied if we can bring strong collaboration to implement positive change using AI.

The 17 Sustainable Development Goals provide an opportunity to multiply the impact as investments move to support implementation. UNGSII are currently using this model to scale and support new business models along with AI to implement the global goals.

Where AI can deliver huge impact will be if individuals can harness the power of shared knowledge between clinician, machine learning and themselves to improve their health and wellbeing. Dr Amir Hannan (NHS GP Manchester) has been providing records access to patients for over 10 years and the opportunities for knowledge transfer to multiply through AI would add significant value to human health and wellbeing worldwide.

The current SDG model focuses on acute care where there will be no doubt benefits, but the open question is, can we harness AI to support people in our communities and move from a gig economy to knowledge.

The cycle HC injection - HC transformation to SC - SC injection in healthcare can be a repeated process. New technologies and innovation are born from the progress of human capital, which then leads to new structural capital, that requires new skills and changed the way human capital operates.

5. Conclusion

Innovation can lead to possibilities that were previously unknown, leading to progress, bringing opportunities for organizations to expand their horizons and knowledge.

Intellectual Capital, defined by its major components of Human Capital, Structural Capital, and Relational Capital is linked to innovation as well as strategy, as Innovation Capital. Medical treatment in Healthcare is a sector that is mostly affected by new innovative technologies. We identified how intellectual capital evolves in the various steps of digital technologies introduction and implementation in the sector of healthcare. The Innovation Capital dimensions of IC might also expand the model above to Social Capital outcome and Societal Capital Impact. The Science Value adds to Health Value, that add to Health Value as well as Societal Value. The Value Galaxy of Intangibles is multiplying beyond the traditional Market Capital.

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