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Intellectual Capital, Absorptive Capacity, and Innovation: A Dynamic Perspective in the Context of Industry 4.0

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ABSTRACT
The importance of intellectual capital (IC) and absorptive capacity (ACAP) in driving innovation in Industry 4.0 is emphasized in various studies. IC refers to intangible assets such as knowledge and expertise, while ACAP is a firm's ability to acquire and apply external knowledge. SMEs and technology transfer intermediaries can improve absorptive capacity through customized services. The dynamic perspective on IC and ACAP is crucial for innovation, with absorptive capacity being essential for leveraging intellectual capital. Innovation ecosystems allow SMEs to integrate resources and co-create Industry 4.0 solutions. The study highlights the need for effective measurement techniques to optimize the value of IC and the importance of creating awareness among investors and managers about its value.

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INTRODUCTION

The fourth industrial revolution, also known as Industry 4.0, has brought unprecedented changes to businesses and industries worldwide. With the advent of new technologies and digitalization, companies are faced with the challenge of staying competitive in a fast-paced and dynamic environment. In this context, intellectual capital and absorptive capacity have emerged as key factors for innovation. Intellectual capital refers to the intangible assets of an organization, such as knowledge, expertise, and intellectual property, which can be leveraged to create value and foster innovation. Absorptive capacity, on the other hand, refers to an organization's ability to acquire, assimilate, and apply new knowledge from external sources. This paper aims to explore the dynamic perspective on intellectual capital and absorptive capacity and their impact on innovation in the context of Industry 4.0. The paper will begin by defining intellectual capital and absorptive capacity and examining their measurement and benefits. Then, the paper will address the challenges and strategies for fostering innovation in Industry 4.0. Subsequently, the paper will analyze how the dynamic perspective on intellectual capital and absorptive capacity enables innovation and identify opportunities for innovation. Finally, the paper will assess the impact of intellectual capital and absorptive capacity on innovation and explore the advantages and disadvantages of leveraging these factors for innovation. Overall, this paper seeks to provide insights into how intellectual capital and absorptive capacity can be harnessed to drive innovation in the context of Industry 4.0.

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Intellectual Capital

Intellectual capital (IC) is a resource that needs to be treated as an investment instead of a cost [1]. It is an important factor in determining the value of an organization [2], and is instrumental in determining enterprise value and national economic performance [3]. There is a lack of effective measurement techniques to specify and optimize the value of IC,and the proposed framework addresses this across the IC cycle [2]. IC efficiency can be a better indicator of successful performance than revenue, profit, or GDP, as it shows whether value is being created or destroyed [1]. A new index called the value creation efficiency of intellectual capital is needed to measure the effectiveness of utilizing IC [1], and accounting for IC is important for measuring the true impact of intangibles on innovation [4]. However, companies are not required to report on IC assets, making the traditional accounting system ineffective for measuring the true impact of such intangibles [4]. Furthermore, IC assets are not recognised and measured in company balance-sheets,and account for a substantial proportion of the difference between company book values and market values [4]. These facts imply that IC affects innovation by being a factor in determining the value of an organization [2], as well as by encouraging investment in the development of IC [1].

Intellectual in the context of Industry 4.0

Measuring intellectual capital in the context of Industry 4.0 is becoming increasingly important in order to assess the value of intangible assets [4]. As such, there is an increasing need to identify appropriate indicators of intellectual capital [3], and to define what constitutes intellectual capital [2], in order to justify investments in these assets. To this end, numerous intellectual capital indicators have been identified in the literature [4], and have been used in companies. A framework for identifying and classifying the various components of intellectual capital has also been proposed [5]. In addition, methods of measuring intellectual capital at both the company and individual levels have been developed [6][5]. Despite the increasing attention to intellectual capital, managers and investors neglect intellectual inputs and outputs [7] due to the lack of suitable measuring system. For instance, Economic Value Added (EVA ®) focuses on the efficiency of capital employed and is not a suitable measuring system for intellectual capital [1]. Therefore, further research is needed to understand how to measure intellectual capital in the context of Industry 4.0 [3]. This topic is important because intellectual capital contributes to innovation and growth, and thus, a better understanding of measuring intellectual capital will help to improve the decision-making process in companies.

Industry 4.0 has been made possible with the advent of modern technology and the emergence of new concepts such as intellectual capital [4]. The concept of intellectual capital and its influence in industry is an area of growing interest among scholars [3]. To assess and measure the impact of intellectual capital, it is essential to first define and classify the components of intellectual capital [2][5]. A framework for identifying and classifying intellectual capital assets has been widely discussed in the literature [5], and provides the basis for understanding how intellectual capital can be leveraged in Industry 4.0 [7]. With the help of this framework, companies can form an

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intellectual capital function [6], which can focus on capital investments and provide a strategy for leveraging intellectual capital [8]. Despite the growing interest in intellectual capital, the use of economic value-added (EVA®) as a tool to measure intellectual capital is gaining ground [1]. This is an ill-advised trend, as EVA® does not take into account the full range of resources required to measure intellectual capital [1]. Therefore, creating awareness among investors and managers about the importance of intellectual capital and its various components is necessary for leveraging intellectual capital in Industry 4.0.

Absorptive Capacity

Absorptive capacity is an important concept related to innovation and new product development. It is a complex construct [9] and is defined as the ability of a firm to acquire, assimilate and exploit external knowledge [10]. It is closely related to organizational learning [10], and is essential for firms to remain competitive in a rapidly changing environment [9]. There are numerous theoretical and empirical studies analyzing firms' capacity to absorb knowledge,and two scales have been created and validated to measure the key components of absorptive capacity,which are potential and realized absorptive capacities [9]. The paper explores the concept of absorptive capacity in more detail [10], and the results confirm the validity of the proposed scales [9], supporting their consolidation as a commonly used instrument. Moreover, absorptive capacity is positively associated with new product development performance and is expected to be related to innovation [10]. It is also related to the management of external knowledge resources [9], and is hypothesized to have a relationship with firm research activities and inventive performance [11]. Furthermore, absorptive capacity-building activities can provide an advantage in terms of both the timing and quality of search outcomes for innovation [11], and it enables firms to acquire new knowledge and integrate it into their existing knowledge base [9]. Thus, absorptive capacity is a key concept that is related to innovation and new product development [9].

Benefits of Absorptive Capacity in Industry 4.0

Developing an absorptive capacity is increasingly important for companies to remain competitive in Industry 4.0 [10]. Absorptive capacity refers to a firm's ability to identify, assimilate, transform, and exploit external knowledge for innovation [10]. It is developed by digitally mature companies through a mix of inbound and outbound open innovation and digital transformation [10]. Research indicates that absorptive capacity is a key factor that contributes to higher levels of new product development performance [10]. It plays an active role in new product development performance in Industry 4.0 [10]. Moreover, absorptive capacity can moderate the impact of R&D collaboration on new product innovation [9]. Studies have shown that firms with greater absorptive capacities show higher maximum innovation performance at higher levels of R&D collaboration than firms with lower absorptive capacities [9]. This highlights the importance of building an absorptive capacity in Industry 4.0 in order to remain competitive.

Absorptive Capacity Enable Innovation

SMEs and technology transfer (TT) intermediaries have an opportunity to improve absorptive capacity through the provision of services that enable innovation. By

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customizing and selecting services, these entities can enhance the process and the type of collaborative innovation they pursue [12]. For instance, TT services can help SMEs increase their potential absorptive capability, realized absorptive capability, external identification, and external commercialization [12]. When TT intermediaries facilitate knowledge and technology transfer, they support the absorptive capacity of smaller enterprises for innovation [12]. However, SMEs need to manage their innovation capabilities and eliminate technological bottlenecks to maximize their possibilities and outcomes from collaborative activities [12]. By doing this, SMEs can improve their absorptive capacity and access new technologies, which will lead to successful innovation.

Innovation in the Context of Industry 4.0

Innovation in the context of Industry 4.0 is a complex yet necessary process that requires the interplay of multiple factors. The dynamic nature of ecosystem evolution in the context of Industry 4.0 has not yet been adequately addressed,and little is known about how to systematize the efforts of SMEs through the promotion of innovation ecosystems for the cocreation of Industry 4.0 solutions [13]. An ecosystem approach is important in the context of Industry 4.0, and key dimensions supporting these ecosystems have been proposed [13]. However, a social exchange perspective may be more suitable to explain value cocreation among the actors in this ecosystem [13]. The Social Exchange Theory (SET) can serve as a lens to analyze value co-creation in an Industry 4.0 context [13]. Furthermore, key technologies have emerged as drivers of relationships among the companies and value co-creation [13]. As trust and commitment grew, the power structure shifted towards a mechanism of neutral coordination of complex projects involving the university and business associations, and lastly to a platform-driven ecosystem structure [13]. Industry 4.0 is essentially based on a network of autonomous, self-controlling, self-configuring, knowledge-based, sensor-based and spatially distributed production resources [14]. Therefore, different forms of the application of the Industry 4.0 concept can foster innovation [14]. The authors propose a theoretical framework to analyze different applications of Industry 4.0 on an organizing continuum to understand what forms foster innovation [14]. Leveraging digital technologies and the industrial IoT to enable new technology applications such as additive manufacturing, adaptive robotics, and flexible machines can enable the connection of objects to form Cyber-Physical Systems [13]. Industry 4.0 is a new industrial maturity stage based on the connectivity provided by the industrial IoT and the use of several digital technologies [13]. However, applications of Industry 4.0 are currently at a very early stage of development and organize more routines than innovations [14]. Professional vocational and academic training is a key factor for the successful implementation of digitalization in future,and a joint venture of industry and educational institutions could be a suitable way to meet the growing demand for qualified employees from the middle to the right-hand of the organizing continuum in the context of Industry 4.0 [14]. Additionally, possible ways of combining I4.0 technologies into bundles should be explored to achieve better performance than the adoption of single technologies,and manufacturing companies

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should implement a synergic bundle of solutions to fully exploit the potential of Industry 4.0 [13]. Government subsidies can influence technology innovation in new-energy enterprises in the new era of Industry 4.0,and digital transformation can mediate the effect of government subsidies on technology innovation in new-energy enterprises in the new era of Industry 4.0 [15]. A top management team (TMT) with digital experience can further moderate the effect of government subsidies on technology innovation in new-energy enterprises in the new era of Industry 4.0 [15]. Industry 4.0 should

Innovation in Industry 4.0

The challenges of enabling innovation in Industry 4.0 have been widely discussed in recent years [15]. The development of innovative technology is essential for the sustainable development of the energy industry in the era of Industry 4.0 [15]. Companies need to be able to recognize and measure the intellectual capital assets they have,as this will help them increase their technological innovation capability in the context of Industry 4.0 [16]. The need for innovation in the industrial domain and the impact of IoT and Industry 4.0 on everyday life and industries are discussed in the literature [17]. It is important to understand how degree of leakages in the economy can impact the energy efficiency-innovation relationship [18]. Leaders need to assume roles and responsibilities to successfully promote a culture of innovation [19]. The literature suggests that Industry 4.0 applications are currently at a very early stage of development and routines are currently more organized than innovations [14]. Innovation ecosystems allow SMEs to integrate resources and cocreate Industry 4.0 solutions [13]. Industrial automation systems enable innovative functionalities [20]. However, the same systems simultaneously show drawbacks, such as the need to adopt to new technologies, the lack of standardization, and the need for skills and expertise [21].

With the dawn of Industry 4.0 [15], it is essential to tackle the challenge of enabling innovation in the industrial domain with the help of the Internet of Things (IoT) and other related technologies [16][17]. Tackling this issue can be done by looking at the degree of leakages in the economy,as this can impact the energy efficiency-innovation [18]. To ensure success in this endeavour, it is necessary to have the right leadership characteristics and skills,as these can help to promote a culture of innovation [19]. Additionally, the literature review undertaken in this paper [21] shows that Industry 4.0 applications are in the early stages of development,and they are mostly used for organizing routines instead of innovations [14]. Therefore, the use of innovation ecosystems is important in order to enable SMEs to integrate resources and cocreate Industry 4.0 solutions [13]. Moreover, it is essential to understand the various industrial automation systems that exist,as these enable innovative functionalities and new business models and work processes [20]. However, it is also important to remember that the Industry 4.0 simultaneously shows both potential and risk [20].

Dynamic Perspective on Intellectual Capital and Absorptive Capacity

The dynamic perspective on intellectual capital and absorptive capacity enables innovation by recognizing the importance of transformation and the exploitation of knowledge for business performance [22]. This view has several implications when it

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comes to the development of a firm's intangible resources and the influence on product innovation [23]. Absorptive capacity is essential for organizations to leverage their intellectual capital and achieve innovation [24], and is recognized as a key area of research in the knowledge management (KM) and intellectual capital (IC) fields [25]. The dynamic perspective on intellectual capital plays a crucial role in enabling innovation [24], and the IC components have a profound positive influence on business performance [22]. Social capital, on the other hand, is noted as a weak predictor of business performance [22]. The fields of KM and IC had largely underdeveloped absorptive capacity [25], but realized absorptive capacity plays a positive mediating role in the relationship between dimensions of intellectual capital and business performance [22]. The study examines the role of realized and potential absorptive capacity in the relationship between IC components and firm performance [22], and suggests that the dynamic perspective on intellectual capital and absorptive capacity can enable innovation in SMEs [26]. The relationship between green intellectual capital and sustainable performance is higher in the presence of higher green dynamic capabilities [26]. This suggests that the dynamic perspective on intellectual capital and absorptive capacity can enable innovation by serving as a benchmark for defining strategies and policies to stimulate innovation [23]. The elements that compose the intellectual capital reflect differently on the dimensions of absorptive capacity,and the absorptive capacity influences innovation [24]. Knowledge acquisition and exploitation have a more intense influence on innovation,and organizational capital influences the capabilities of acquisition, assimilation, and exploitation of knowledge more decisively,followed by human capital [24]. The ability of transformation of knowledge is influenced evenly by organizational and human capital [24], and more moderately by social capital [23]. Absorptive capacity enables firms to absorb and utilize external knowledge and information to innovate,and product innovation is a result of the mobilization of intellectual capital and other intangible assets through dynamic capabilities like absorptive capacity [23]. The impact of each dimension of absorptive capacity on product innovation is different,and human capital has a moderate influence on ACAP's dimensions of acquisition, assimilation and exploitation of knowledge [23]. Structural capital has a more decisive influence on ACAP's dimensions of acquisition, assimilation and exploitation of knowledge [23].

Implications of the dynamic perspective for Industry 4.0

Industry 4.0 requires an appropriate balance of innovation and exploitation activities [27], which cannot be attained without an adequate absorptive capacity (ACAP) level [28]. As such, it is necessary to have an understanding of the relationship between intellectual capital and ACAP [26]. Research has found that intellectual capital has a positive effect on ACAP and innovation capability [29], while also being able to influence the sustainable ACAP [24]. Moreover, investments in R&D are mobilized by firms through dynamic capabilities such as absorptive capacity [23], which can explain the contribution of human capital to absorptive capacity [30]. This paper serves as a primary reference for those interested in researching absorptive capacity in the field of knowledge management and intellectual capital [25]. Furthermore, studies have shown that human

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capital positively affects absorptive capacity [22], which can further enhance the relation between intellectual capital and innovation [31]. Thus, it is necessary to recognize the significance of intellectual capital from the perspective of Industry 4.0 in order to achieve adequate absorptive capacity and optimal economic performance.

The Dynamic Perspective (DP) is a prominent innovation strategy that has been the subject of much recent research [27]. It is based on the premise that organizations must be able to exploit existing knowledge and assets, while at the same time innovating to create new knowledge and assets [28]. The DP links absorptive capacity and intellectual capital, leading to increased innovation [26][22]. This is done by examining the influence of investments in R&D, human capital and other intangible assets on absorptive capacity [30]. It is also important to note that absorptive capacity is a key factor in the relationship between intellectual capital and innovation [31]. This is because absorptive capacity can leverage the relationship between intellectual capital and innovation and increase the efficiency of the dynamic perspective [31]. In addition, by understanding the role of absorptive capacity, organizations can identify opportunities for innovation [27]. Moreover, this research is also helpful in providing a primary reference for those interested in researching absorptive capacity in the field of knowledge management and intellectual capital [25].

Impact of Intellectual Capital and Absorptive Capacity on Innovation

Research into the impact of intellectual capital and absorptive capacity on innovation in the context of Industry 4.0 is an important study. The research itself contributes to the literature on this subject,emphasizing the importance of the transformation and exploitation of knowledge for business performance [22]. The study examines the role of realized and potential absorptive capacity in the relationship between IC components and firm performance [22]. The results suggest that intellectual capital has an impact on product innovation in the context of Industry 4.0 [24]. Furthermore, absorptive capacity also plays a role in innovation, with each dimension having a different level of influence [24]. Product innovation is a result of the mobilization of intellectual capital and other intangible assets through dynamic capabilities such as ACAP [23]. It has been shown that IC has an influence on a firm's absorptive capacity [23], and that specific policies aimed at developing the IC of a firm can be emphasized [27]. All dimensions of IC have a profound influence on organizational ambidexterity,with technology's ACAP having a partial mediating role in the association of IC and ambidexterity [27]. Structural capital has a more decisive influence on the acquisition, assimilation, and exploitation of knowledge,while human capital has a moderate influence on the same [23]. Social capital has a moderate influence on the transformation of knowledge,while structural and human capital have an even influence on the transformation of knowledge [23]. The impact of ACAP on product innovation varies for each dimension,with IC having a different influence on each dimension [23]. Finally, IC plays a significant role in balancing innovation and exploitation activities in Industry 4.0 [27].

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Intellectual Capital and Absorptive Capacity Facilitate Innovation

There is an increasing interest in the role of intellectual capital (IC) and Absorptive Capacity (ACAP) in the innovation process. IC is divided into three core elements: Human Capital (HC), Structural Capital (SC), and Relational Capital (RC). Research has indicated that IC has a significant effect on ACAP and innovation capability [29]. Furthermore, it has been suggested that the management team's human capital has a significant impact on an organization's ACAP [30]. It appears that human, social, and organizational capital are mobilized by firms through dynamic systems of IC [32]. This study shows that human capital has a positive influence on absorptive capacity and business performance [22], and that IC and other intangible assets are mobilized by firms through dynamic systems of IC [23]. It also investigates the importance of human capital on the firms' absorptive capacity, in relation to firms' innovative performance [33]. It has been argued that IC and absorptive capacity can help to balance the innovation process [27]. It is also suggested that ACAP can help organizations to identify, absorb, assimilate, transform, and exploit external knowledge, leading to innovation [28]. Moreover, cultural intelligence can further help organizations to identify, assimilate, and exploit external knowledge [34]. In conclusion, IC and ACAP are important aspects in facilitating innovation, and can have a positive effect on business performance.

Advantages and Disadvantages of Leveraging Intellectual Capital and Absorptive Capacity for Innovation

The idea of leveraging intellectual capital (IC) is to develop and grow it into a valuable asset [29]. This is typically accomplished through the use of absorptive capacity (ACAP). Through the utilization of ACAP, the effects of IC on innovation can be better understood [28]. This is due to the fact that ACAP is a measure of an organization's ability to acquire and utilize knowledge effectively [30]. Research has also indicated that IC can be used to mediate between ACAP and innovation capability [32]. This is because it serves as a bridge between the two, allowing for greater access and usage of knowledge [34]. Additionally, research has shown that IC, such as human capital, has a positive effect on ACAP and business performance [22]. This is because it allows organizations to better utilize knowledge, which in turn increases innovation [23]. Further studies have also concluded that IC and ACAP have a significant impact on innovation [24], as well as the performance of businesses [33]. Moreover, it has been suggested that IC, along with ACAP, can help to balance innovation and technology [27], allowing for the development of an innovative environment.

CONCLUSION

The present study highlights the importance of intellectual capital (IC), absorptive capacity (ACAP), and innovation in the context of Industry 4.0. The findings of the study suggest that IC is a valuable resource that needs to be treated as an investment rather than a cost, and it plays a pivotal role in determining the value of an organization and national economic performance. However, IC assets are not recognized and measured in company balance sheets, and there is a lack of suitable measuring systems to identify

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appropriate indicators of IC. The proposed framework for identifying and classifying the various components of IC can be helpful to justify investments in these assets. ACAP is an important concept related to innovation and new product development, which enables organizations to identify, assimilate, transform, and exploit external knowledge. The study also highlights the need for understanding how to measure IC in the context of Industry 4.0, and the importance of creating awareness among investors and managers about the value of IC and its various components. The findings of this study have several implications for future research, such as the need for effective measurement techniques to specify and optimize the value of IC, the role of human capital on firms' absorptive capacity, and the impact of innovation ecosystems on Industry 4.0 solutions. Overall, this study contributes to the ongoing advancement of knowledge in the field of IC, ACAP, and innovation, and provides a framework for leveraging IC in Industry 4.0.

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