The Strategic Role of Entrepreneurial Computer Engineers in Shaping Innovation Ecosystems: Innovation Engineering

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Abstract

Purpose: This paper investigates the critical role of entrepreneurial computer engineers in driving innovation and accelerating economic growth through the creation of technological businesses. By analyzing their contributions to innovation ecosystems, we aim to provide insights into the unique impact these engineers have within the entrepreneurial landscape. The study underscores the need for tailored policies that harness the potential of entrepreneurial computer engineers to achieve macroeconomic objectives amidst ever-changing economic complexities.

Design/methodology/approach: To examine the significance of entrepreneurial computer engineers within the innovation ecosystem, this study employs bibliometric analysis with VOS viewer to explore existing literature on engineering and entrepreneurship.

Findings: Using bibliometric analysis, we reveal a network of interconnected skills such as risk-taking, self-determination, and project-based learning, evident in the co-occurrence of keywords.

Originality: This paper addresses the under-researched topic of engineering entrepreneurship in relation to innovation, aiming to provide knowledge and insights into the intersection of engineering and entrepreneurship. By examining this nexus, the paper contributes to filling the gap in existing literature and offers valuable perspectives for both academia and industry.

Practical implications: The entrepreneurial computer engineer plays a central role in steering technical innovation and fostering sustainable economic growth within the field of computer engineering. We pinpoint specific skills and strategic pathways crucial for the growth and development of entrepreneurial computer engineers, emphasizing the unique contributions and challenges within this domain.

Keywords: Entrepreneurial Engineering, Innovation Ecosystem, computer engineer, Innovation engineering

Introduction

Creating sustainable growth in one's environment requires aligning knowledge with the ability to make a tangible impact. Engineers play a crucial role in designing and implementing procedures for sustainable product production. Policy makers and managers recognize the importance of influential individuals in driving economic growth, and entrepreneurs have emerged as key contributors, using innovative ideas to address issues in line with sustainable development goals (Seelos and Mair, 2005; Buotillier, 2021; Filion, 2021). This integration of engineering and economics in business and entrepreneurship has given rise to a new breed of engineers focused on developing high-tech businesses (Roberts, 1991). Engineers possess diverse technical skills across disciplines such as civil, mechanical, computer, chemical, and aerospace engineering, using scientific principles to design and optimize products and systems in various industries, driving sustainable growth and innovation across multiple sectors (Wood, 2012).

Sustainable growth has emerged as a modern approach to progress, focusing on correcting past mistakes and ensuring holistic advancement to meet human needs effectively (Drioli and Fontananova, 2004). Entrepreneurs play a key role in this shift by adopting sustainable mindsets in their endeavors. Although contributions to sustainable growth vary among individuals, engineering professionals often hold more positive views towards sustainability (Azapagic *et al*., 2005). This perspective shapes entrepreneurial computer engineers' behaviours, who focus on sustainable practices in their work. These engineers drive technological progress in innovation ecosystems by creating and implementing technical ideas, using both software and hardware components (Hennessy and Patterson, 2011). Often displaying entrepreneurial skills, they innovate products and establish businesses to bring technologies to market. This blend of technical expertise and business acumen enables them to make substantial contributions to the long-term sustainability of innovation ecosystems. Through their active involvement in technological advancements, computer engineers become key drivers of progress, ensuring continued growth and prosperity of the ecosystems (Goldberg, 2006; Schilling, 2012; Swamidass, 2016).

The pivotal role of entrepreneurial computer engineers in the advancement of the innovation ecosystems cannot be overstated (Doboli *et al*., 2010). These exceptional individuals often possess a unique blend of technical prowess and business acumen, which empowers them to recognize unexplored prospects and effectively translate groundbreaking concepts into thriving enterprises. In their pursuit, they actively engage with various stakeholders within the ecosystem, such as investors, researchers, and policymakers, to cultivate an environment that fosters the flourishing of innovation. Through their collaborative efforts, they shape a landscape where novel ideas can drive progress (Kuhrmann et al., 2022).

The literature studied focuses mostly on entrepreneurial computer engineers, highlighting their importance in technical innovation and commercial development. While these studies highlight the critical role of computer engineers in driving engineering advancements and fostering innovation ecosystems (Harb and Shang, 2021; Audretsch et al.,2022), some scholars warn against emphasizing technical skills over broader entrepreneurial competencies (Ogrizek Biškupić, 2023; Neumeyer and Santos, 2021). Furthermore, critics argue that the entrepreneurial spirit created by computer engineers does not necessarily transition effortlessly into successful commercial endeavors, emphasizing the importance of a comprehensive grasp of the issues they encounter (Rusu and Rusu, 2023). Despite the recognition of their achievements, there remains a void in the literature about the long-term sustainability of entrepreneurial businesses begun by computer

engineers, warranting greater research into the results and impacts of their entrepreneurial initiatives (Rae and Melton, 2017; Duval-Couetil, 2012; Gerba, 2012; Maresch, 2016).

Successful entrepreneurial computer engineers often possess a rare combination of technical competence and commercial acumen, enabling them to lead technology developments and create innovative business models and ecosystems. Through experience and learning, they refine their skills in both engineering and business management, which are crucial for navigating the complexities of technology commercialization and fostering collaborations (Okokpujie *et al*., 2019; Autio, 1997; Davis, 2006; Gawer and Cusumano, 2014). This expertise is cultivated through a variety of sources including formal education, professional experience, and continuous learning opportunities, empowering them to discover new possibilities, effectively manage resources, and foster collaboration among stakeholders in the innovation ecosystem.

Innovation and economic growth are intricately linked to the presence of forward-thinking entrepreneurs who leverage technology in their endeavors (Mason and Brown, 2014). This dynamic ecosystem comprises various components such as universities, research institutions, startups, venture capitalists, and established companies, all working together to drive innovation forward (Pierrakis and Saridakis, 2019; Rossi *et al*., 2021; Marcon and Ribeiro, 2021; Gupta *et al*., 2022; Song, 2022). Within this ecosystem, entrepreneurial engineers play a pivotal role by harnessing their engineering expertise to create and establish high-tech businesses towards high-tech entrepreneurial ecosystem development (Bonnema, 2011; Mason and Brown, 2014; *Acs et al*., 2017; Theodoraki et al., 2018). Consequently, the growth in the number of entrepreneurial engineers within an innovation ecosystem propels sustainable economic development by fueling the establishment of innovative and technologically advanced enterprises (Sheriff and Muffatto, 2018).

In this research paper, our main objective is to delve into the distinctive qualities possessed by computer engineers with an entrepreneurial mindset and emphasize their pivotal role in propelling the innovation ecosystem forward. To achieve this, we conduct an extensive review of the existing literature, providing a comprehensive analysis of why these individuals are uniquely positioned to make substantial contributions to the advancement of the contemporary innovation landscape. Our central research question is: " What are the skills and capabilities that have a higher occurrence in literature? and how do these qualities contribute to the advancement of the contemporary innovation landscape?". Furthermore, we adopt a broader perspective by employing a bird's-eye view approach, which involves scrutinizing the fundamental concepts in this field by analyzing the interconnectedness of keywords within a co-occurrence network with VOS viewer (Van Eck and Waltman, 2010; Van Eck and Waltman, 2014). This method allows us to gain a holistic understanding of the subject matter, revealing the intricate relationships and associations that exist among various concepts and ideas.

By undertaking this research, we aim to shed light on the invaluable contributions of entrepreneurial computer engineers and underscore their significance in driving innovation, ultimately providing insights that can contribute to greater understanding of digital ecosystem development. Since these individuals specialize in computer technology, their insights and experiences are particularly relevant for shaping the new age of innovation ecosystem.

Literature Review

Engineering, Design thinking and Entrepreneurship

For a significant duration, engineers have been engaged in the process of conceptualizing and shaping ideas, preparing them for practical realization in the real world. As an idea advances towards its transformation into a tangible product, it traverses through multiple stages that involve the collaboration of various individuals. Throughout this journey, engineers employ the principles of design thinking, a problem-solving approach that enables them to effectively engineer ideas and bring them to life as concrete products (Kimbell, 2011; Kelessidis, 2013).

However, the successful navigation of this complex process in the marketplace requires individuals to possess a broader understanding of business dynamics, especially entrepreneurship. Acquiring knowledge in this domain becomes crucial as it equips individuals with the managerial skills necessary to convert their ideas into viable products (Goldberg, 2006; Svensson *et al*., 2020).

By embracing design thinking methodologies, engineers not only optimize the ideation and engineering phases but also embrace a holistic approach that takes into account market viability and customer needs. This iterative process involves continuous refinement and adaptation, ensuring that the final product aligns with market demands and satisfies user requirements (Rösch *et al*., 2023). Additionally, by integrating business and entrepreneurial knowledge, engineers gain insights into strategic planning, market analysis, resource allocation, and other essential aspects, enabling them to effectively navigate the intricate landscape of transforming ideas into successful products.

In essence, the convergence of design thinking and entrepreneurship provides engineers with a comprehensive toolkit to guide them from ideation to product realization (Tschimmel, 2012). This interdisciplinary approach ensures that engineers not only excel in the technical aspects of their work but also possess the business acumen necessary to transform their innovative ideas into tangible and marketable solutions.

The modern world has witnessed a shift in focus towards business management concepts and knowledge among economists, leading to a greater complexity in the sciences and background understanding associated with economic development. Consequently, the field of engineering education has evolved to incorporate business management skills and mindsets, with a particular emphasis on fostering an entrepreneurial spirit. This shift has been supported by numerous studies and authors, indicating the growing recognition of the importance of entrepreneurship (Bosman and Fernhaber, 2018; Elia *et al*., 2017; Polczynski and Jaskolski, 2005; Antonites, 2012),

As a result, there has been a rise in the establishment of educational institutions, such as universities, aimed at training engineers who possess both technical expertise and the ability to manage businesses effectively (Vohora et al., 2004). These institutions recognize the need for engineers with an entrepreneurial mentality to drive advancements in modern industries. This paradigm shift reflects the evolving landscape of engineering education, where the integration of business management skills and entrepreneurial thinking is seen as crucial for fostering innovation and driving economic growth. (Chorev and Anderson, 2006; Elia *et al*., 2011; Landers, 2020; Secundo *et al*., 2013; Secundo *et al*., 2015; João *et al*., 2020).

Entrepreneurial engineers are individuals who develop their mindset by acquiring knowledge related to business while also embracing hands-on and minds-on learning approaches such as

STEM. This enables them to effectively prepare themselves for practical entrepreneurship, as emphasized by various researchers (Tryggvason and Apelian, 2006; Petersen, 2012; Acs *et al*., 2016; Sörensen, 2022; Colombelli, 2022; Pachnowski *et al*., 2023).

Moreover, Entrepreneurial computer engineers contribute a unique combination of commercial knowledge and technical expertise in computing technologies to innovation ecosystems (Gruber and Henkel, 2006). Their innovative thinking, collaborative ability, risk management knowledge, leadership abilities, marketing competence, and quality control aptitude enable them to generate development in these ecosystems (Moreno *et al*., 2022). With this diverse skill set, they can successfully manage the complete innovation process inside commercial contexts. The impact of these characteristics on entrepreneurial success has been thoroughly demonstrated in several studies (Farr and Brazil, 2009; Gebhardt, 2005; Aadland and Aaboen, 2020; Gaddam *et al*., 2016).

In summary, entrepreneurial engineers not only acquire business-related knowledge but also adopt practical learning approaches like STEM. By combining business and computing technology skills (Such as big data analytics), including various key competencies, they become well-equipped to drive innovation within businesses (Bonnema, 2011; Makhloufi, 2024). The importance of these attributes has been substantiated by a range of researchers in the field (Huang-Saad *et al*., 2020; Almeida and Daniel, 2021;Bugaian, 2022; Makhloufi *et al*.,2023; Kidman et al., 2023).

Entrepreneurial computer engineers with a strong technical background possess a unique mindset that combines technology and business acumen, making them invaluable in establishing cutting-edge businesses across various scenarios (Higuera and Culshaw, 2008). Their ability to integrate emerging technologies is vital as they navigate the complexities of the rapidly evolving tech landscape and actively develop their cognitive abilities to support business growth. This evolution of engineers into entrepreneurs is a result of the intricate interplay between science, technology, and business, which has led to engineers becoming integral members of business teams, contributing to the creation of innovative technological products towards tackling real-world challenges (Huang-Saad *et al*., 2020, Zahra, 2008). However, it is worth noting that not all engineers pursue entrepreneurship in the traditional sense, as some opt to become intrapreneurs, injecting innovation into their respective organizations (Chang, 2015).These engineers possess a rare set of skills, including in-depth knowledge of the market's "Wh" questions (who, what, why, when, and where), allowing them to transform innovative ideas into successful businesses (Gebhardt, 2005). With a profound understanding of technical concepts and principles, these professionals demonstrate their high level of expertise.

In summary, Entrepreneurial computer engineers flourish because of their unique combination of technical knowledge and business drive. They employ their extensive knowledge of industry complexities and excellent problem-solving ability to create significant solutions for technology replacement in the market (Shane, 2000). Their outstanding communication and teamwork abilities allow them to collaborate with specialists from other sectors to effectively realize their business goals. These engineers show courage and dedication by spending their time and money to bring breakthrough ideas to fruition. They welcome risk and see failure as a great learning tool in their pursuit of knowledge and progress. Driven by enthusiasm, they aspire to make significant contributions to society through unique breakthroughs (Shane and Venkataraman, 2000).

Ecosystem Development towards Digital age

The significance of the innovation ecosystem has become increasingly recognized by policymakers as they strive for sustainable development (Granstrand and Holgersson, 2020; Gu *et al*., 2021). When we talk about an innovation ecosystem, we are referring to a dynamic interplay of specific natural components that convert the process of innovation into an economic endeavor (Adner, 2017; Shaw and Allen, 2018). Over time, this field has seen the emergence of three distinct categories: the business ecosystem, the technology ecosystem, and the entrepreneurship ecosystem (Meng and Ma, 2018; Foguesatto and Santini, 2021). These categories delineate the interrelationships between them and aim to promote economic growth through technological advancements driven by businesses (Xu *et al*., 2018; Souminen *et al*., 2019).

However, further exploration in this field by Klimas and Czakon has uncovered five additional categories that provide a deeper understanding of the innovation ecosystem. These categories include (1) life cycle, (2) structure, (3) innovation focus, (4) scope of activities, and (5) performance (Klimas and Czakon, 2022). By examining these aspects, researchers and policymakers can gain more comprehensive insights into the intricacies of the innovation ecosystem and its potential impact on economic development.

The foundational work of Granstrand and Holgersson (2020), along with their peers, casts a spotlight on the dynamic interplay among the various components of innovation ecosystems, drawing a parallel with the intricate relationships observed in natural ecosystems. This comparison not only enriches our conceptual grasp of these ecosystems but also broadens the scope of "innovative performance" to encompass a spectrum that includes both groundbreaking innovations and strategic imitations, thereby offering a more holistic economic outlook.

As described by Moore (1993), the innovation ecosystem emerges as companies and institutions adjust and evolve in response to technological and scientific progress, driven by their goals and objectives. Consequently, this dynamic process establishes a competitive environment where all elements of the innovation ecosystem actively engage in enhancing their capabilities through innovation. Over time, this ongoing interaction leads to the emergence of new actors and novel innovations. Therefore, in today's digital era, the players and components comprising the innovation ecosystem have continually transformed in alignment with their technological advancements, adapting and evolving to meet the demands of the changing landscape.

In today's digital era, the various industries have undergone a significant transformation due to digitization, leading to a complete overhaul of the elements that make up an innovation ecosystem. Traditional components have been replaced by technological ones, resulting in the emergence of a digital ecosystem that nurtures and enhances the capabilities for business innovation. This transformation introduces new actors with enhanced abilities, as highlighted by Subramaniam *et al*. (2005), Weill and Woerner (2015), Sussan *et al*. (2017), and Autio *et al*. (2018).

At the same time, universities and industries, recognized as vital participants within the innovation ecosystem, are experiencing dynamic changes. They engage in collaborative efforts and evolve simultaneously, with the shared objective of establishing a vibrant and continually evolving innovation ecosystem, as described by Etzkowitz and Leydesdorff (2000). Consequently, innovation ecosystems operate as dynamic systems, constantly evolving by integrating

technological advancements, academic and industrial innovation, and entrepreneurial developments to enhance their system components.

Businesses and firms play a vital role in the innovation ecosystem by actively driving its dynamism. They aim to promote sustainable development within their countries through extensive research and development efforts (Traitler *et al*., 2011). As the driving force behind these businesses, entrepreneurs bear the responsibility of leading their organizations and must employ adaptive strategies to embrace technological advancements within their operations. It is crucial for entrepreneurs to remain flexible and responsive to the ever-evolving landscape of open innovation within the innovation ecosystem (Teece, 2014; Bogers *et al.*, 2019; Teece *et al*., 2016; Leckel *et al*., 2020). By doing so, they can effectively navigate the shifting paradigms and seize opportunities for growth and success.

Data and Methodology

In this article, an attempt has been made to examine the semantic relationship between engineering and entrepreneurship and specifically the role of computer engineers by considering the following two key questions:

- What are the skills and capabilities that have a higher occurrence in literature?
- What subjects capture the attention of intellectuals within the realm of entrepreneurial engineering?

In order to answer these questions, scientific documents were extracted in the WOS database and then analyzed using the network co-occurrence method through the VOS viewer software.

Data Collection

The researchers of this study, for literary and scientific discoveries from intellectuals in the related field, the WOS database was chosen as an interdisciplinary resource and providing the opportunity to discover new information through cloud data and citation communication (Falagas *et al*., 2008; Bakkalbasi *et al*., 2006; Bar-llan, 2008).

In order to consider the scientific documents about entrepreneurial engineers, the concepts of "entrepreneurship*" and "engineer" were included in the search field. In addition, no asterisk was placed after this concept to extract scientific documents that mentioned the engineer as a person rather than an (engineering) activity. Because the search comes across articles that talk about "engineering", "reverse engineering", etc., which are not related to the field of this research.

By restricting the language of scientific documents to English, 258 scientific documents in the period 1965-2023 were extracted for analysis with VOS viewer software.

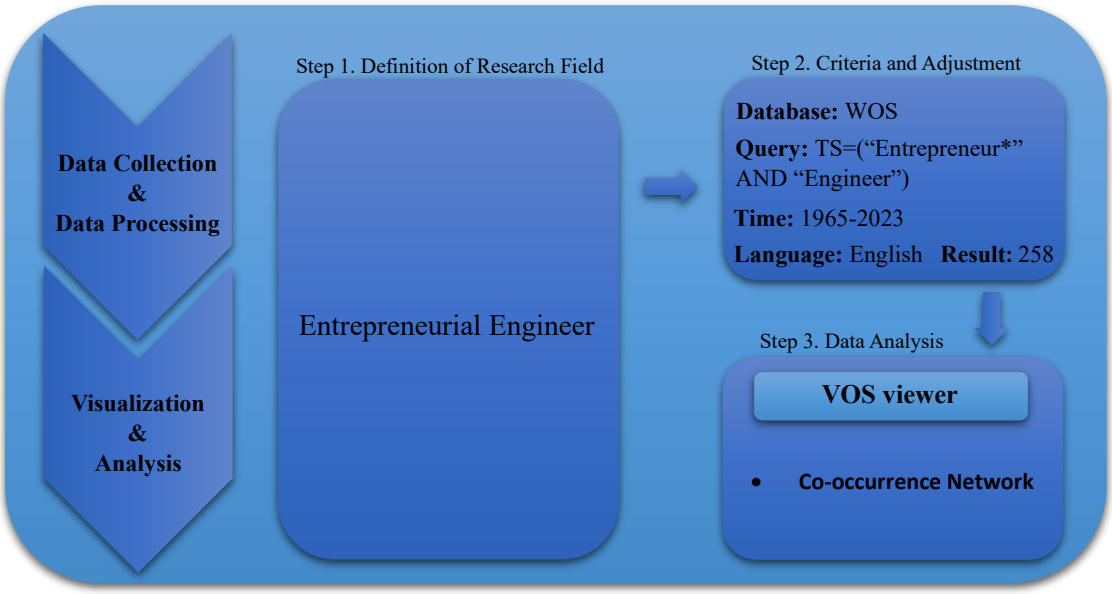

Figure 1: Data and Methodology Model

Data Analysis

The bibliometric method employs quantitative analysis to provide a quantitative description of qualitative features (Wallin, 2005). By adopting a general network framework and taking into account the study's research questions, we can tap into the expertise and accomplishments of intellectuals in the field of entrepreneurial engineers, as manifested through their consistent activity and scientific achievements over time. This approach allows for a comprehensive examination of their own research contributions, integrating the knowledge they have generated, with the aim of informing policy-making and strategic decision-making (Van Leeuwen, 2003).

Co-Occurrence Network

Co-occurrence networks are based on the idea that terms that appear together frequently in a text corpus are likely to be related or share some common meaning (Gries and Durrant, 2021). By default, the VOS viewer software places the nodes of a network in a cluster according to their close semantic relationship for the word co-occurrence network. The number of clusters and the method of measuring nodes are calculated according to the degree of similarity and semantic distance between them with the following parameter and formula (Fortunato, 2010; Fortunato and Hric, 2016; Van Eck and Waltman, 2010).

$$Co - Occurrence(C_i, C_i) = \sum_{k=0}^{n} f(k, D)$$

In here, where C_{ij} is the number of times term i and term j Co-occur in text corpus. For more, f and $C_i$defined as follows:

$$f(k, D) = \begin{cases} 1, if\ [C_i \in dk\ \Lambda\ C_j \in d_k \\ 0, otherwise \end{cases}$$

Also, in this mapping technique, VOS viewer evaluates the ability to recognize the similarity and normalizing co-occurrence of concepts in texts through a matrix. To do this, the saturation S_{ij} between two items i and j is calculated as follows (Van Eck and Waltman, 2010).

$$S_{ij} = \frac{C_{ij}}{W_i W_j}$$

$$C = \begin{bmatrix} C_{11} & C_{12} & \cdots & C_{1n} \\ C_{21} & C_{22} & \cdots & C_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ C_{n1} & C_{2n} & \cdots & C_{nn} \end{bmatrix}$$

Finally, after weighting the concepts according to their reproducibility in scientific documents and calculating them through the above formulas, in the final network; According to the similarity of the concepts and the degree of their semantic connection, it is calculated through the formula of the final co-occurrence network.

$$S_{ij} = \frac{n_{ij}}{\sqrt{n_i} n_j}$$

where Sij is the similarity between items i and j, n_{ij} is the number of times that items i and j co-occur, and n_i and n; are the total occurrences of items i and j, respectively.

Finally, the authors of the study sought to investigate the specific concepts that intellectuals in the domains of engineering and entrepreneurship engage with. To tackle this inquiry, we utilized VOS software to measure the co-occurrence network of keywords found in scientific documents. The analysis encompassed both authors' keywords and general keywords. In order to ensure an adequate representation of concepts, the authors established a minimum word occurrence threshold of 2. This meticulous approach aimed to comprehensively capture and explore the interconnectedness of ideas within these fields of study.

Results

Mapping the Interconnected Skills of Entrepreneurial Computer Engineers

The figure presented as Figure 1 illustrates a co-occurrence network that establishes connections between keywords based on the likelihood of their appearance among researchers. Several key concepts such as model, policy, engineer, education, research, and enterprises emerge within this network, and their interactions, as well as the changes and advancements in the model, contribute to the training of engineers with new policies.

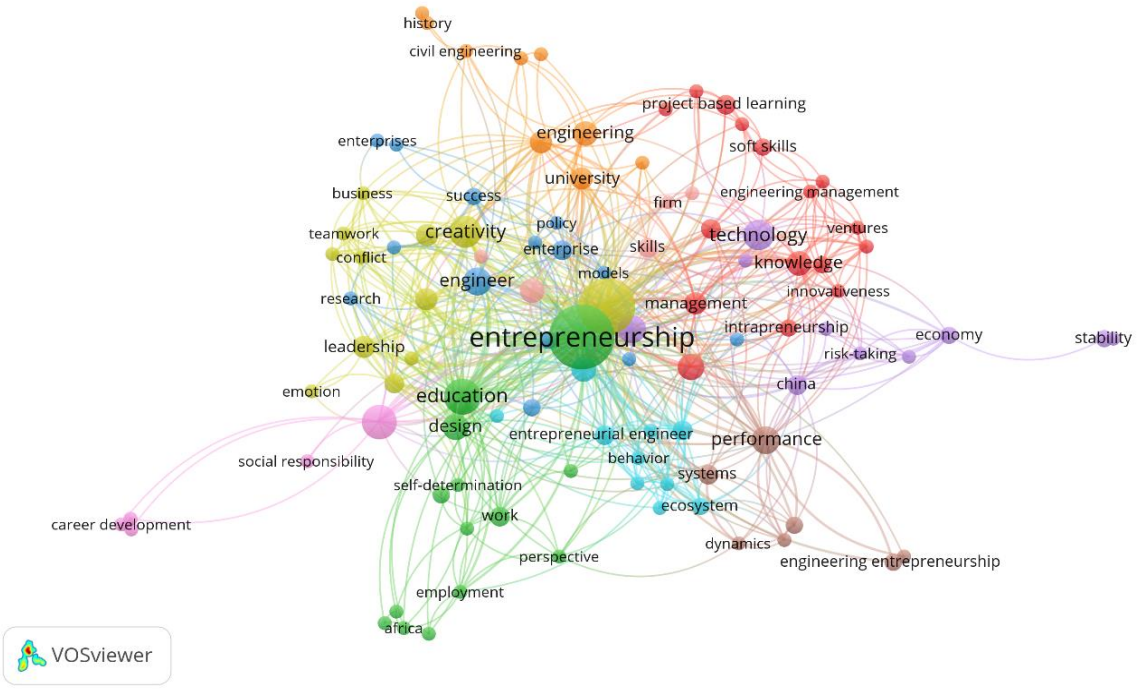

Figure 1: Co-occurrence network of keywords

This network highlights the importance of exploring the newly identified capabilities of engineers within the innovation ecosystem, particularly in relation to innovation and entrepreneurship. Concepts such as project-based learning, skills, creativity, leadership, risk-taking, self-determination, social responsibility, technology, and the economy are associated with each other and underscore the significance of developing the skills of engineers in entrepreneurship, business management, and technopreneurship creation. These efforts are crucial for advancing innovation strategies and fostering economic growth within the innovation ecosystem**.**

By considering the capabilities and skills within the network identified above, a human-resource based strategy can be formulated to guide the development of an entrepreneurship or innovation ecosystem, ultimately contributing to economic growth. Previous research by Adner (2006), Amante and Ronquillo (2017), Teece and Pisano (2003), Audretsch and Keilbach (2004), and Urbano and Aparicio (2016) has also emphasized the importance of these factors in shaping innovation strategies and fostering economic progress.

Cluster's Color	Concepts	Semantic tags	Socio-Political Landscape Examination
Green	• Education • Design • Self-Determination • Employment • Perspective • Work	Entrepreneurial Firm	Entrepreneurial computer engineers in companies can independently develop software, design innovative applications, develop blockchain technology and artificial intelligence to facilitate internal processes and customer services (Jia,2023).
Brown	• Performance • System • Dynamics	Manageability design	The development of Manageability design for entrepreneurial computer engineers leads to increased performance in line with

	• Engineering Entrepreneurship		technological product design. Also, it will develop system performance in line with strategic and commercial goals (Martin, 2009).
Purple	• Stability • Economy • Risk-Taking • Technology	Strategic Development Nexus	Computer engineers who embrace risk-taking and exhibit entrepreneurial qualities play a leading role in the innovation ecosystem, driving technological progress and facilitating the creation of solutions, products, and economic advancements.
Red	• Ventures • Engineering Management • Soft Skills • Project-Based Learning • Management • Innovativeness • Intrapreneurship	Team Competency Perspective & Engineering Management Education	A comprehensive training program of technical competence and soft skills is necessary to increase entrepreneurial computer engineers and their entrepreneurial spirit. which can be focused by integrating soft skills and project-based learning in a working group to drive innovation in companies.
Yellow	• Creativity • Leadership • Teamwork • Business • Emotion • Conflict	Aspiring Engineer's Mindset for Entrepreneurship	The path of an aspiring computer engineer in entrepreneurship with a mindset which consists of: creativity, leadership, teamwork (collectivist), emotional intelligence and conflict management (Fisher *et al*., 2011). By integrating these elements in engineering education, we can create the next generation of entrepreneurs in the new era.

Table-1: Summary table and network labeling

In general, entrepreneurial computer engineers with technical, informational and business management abilities can be considered as the main drivers of innovation and development in modern era entrepreneurship. As can be seen in the table above, according to the emerging concepts in entrepreneurial engineering and considering the characteristics of computer engineers that have a high semantic connection in technological innovation for economic development, a new strategy and policy can be designed for the creation and cultivation of technological entrepreneurs in the new age. (Wennekers and Thurik, 1999; Shane, 2009; Brynjolfsson and McAfee, 2014).

Driving Innovation: The Role of Entrepreneurial Computer Engineers

As previously mentioned, the process of engineering ideas holds considerable influence over the real world. In today's ever-evolving landscape, where entrepreneurs play a crucial role in driving economic development, it becomes imperative to emphasize the integration of their technical expertise and soft skills across diverse fields within the innovation ecosystem (James-Acero *et al.*, 2022).

In light of this, entrepreneurial engineers must adapt and enhance their capabilities over time to align with the changing market dynamics and business environment. The versatility of these entrepreneurs is nurtured through the development of educational frameworks tailored to meet the needs of entrepreneurial engineers (Täks *et al*., 2016; Svensson *et al*., 2020).

Moreover, computer engineers are widely acknowledged as significant contributors in the modern technological era, particularly due to their involvement in both hardware and software

development within the commercial sector. Their expertise plays a pivotal role in driving technological advancements that shape our current digital landscape. Entrepreneurial computer engineers are a valuable breed of entrepreneurs who fuel technological advancement by establishing cutting-edge businesses within innovation ecosystems. Their presence not only fosters the growth of high-tech enterprises but also fosters the development of leadership within a country's innovation ecosystem (Jia, 2023). These engineers possess dynamic capabilities that make them highly adaptable in the realms of competition and technology advancement. Consequently, when considering economic development policies, it becomes evident that entrepreneurial engineers play a crucial role in achieving sustainable progress through the implementation of modern technologies, thus contributing to the overarching goals of an innovation ecosystem. By incorporating the interconnected concepts of technology, engineering, entrepreneurship, and ecosystem, we can shed light on the significant responsibilities held by entrepreneurial engineers:

1. Driving Technological Innovation: Entrepreneurial engineers act as catalysts for sustainable technological innovation within various industries. They actively contribute to the creation and implementation of groundbreaking ideas, ensuring that advancements align with the principles of sustainable development (Sarasvathy and Venkataraman, 2011).

2. Establishing High-Tech Ventures: These engineers play a pivotal role in establishing and nurturing high-tech businesses within innovation ecosystems. By leveraging their expertise, they create entrepreneurial ventures that are at the forefront of technological advancements, thereby fueling the growth and competitiveness of the ecosystem as defined in Table 1's red cluster (Kakati, 2003; Colombo, 2021).

3. Enabling Technological Integration: Entrepreneurial computer engineers facilitate the seamless integration of technologies through their expertise in both technology and business development. They bridge the gap between technical innovation and market demands, driving the successful adoption and integration of emerging technologies into various sectors (Welsum, 2016; Schuelke-Leech, 2018).

In summary, entrepreneurial computer engineers are instrumental in propelling technological innovation, establishing high-tech businesses, and facilitating the integration of technologies within innovation ecosystems (Braguinsky *et al.*, 2012; Mukhtarova *et al.*, 2019). Their multidimensional roles contribute to the sustainable development of industries and the overall success of an innovation-driven economy.

Entrepreneurial engineers play three essential roles within the innovation ecosystem, and these roles are instrumental in driving sustainable development in today's industrial landscape. By assuming these roles, entrepreneurial engineers actively contribute to fostering innovation and propelling the progress of industries towards a sustainable future.

The first role entails being initiators and catalysts of innovation. Entrepreneurial engineers, armed with their technical expertise and entrepreneurial mindset, actively generate new ideas, technologies, and solutions that address pressing challenges faced by industries. They have the unique ability to identify gaps and opportunities in the market, leading to the development of groundbreaking innovations. By taking the initiative and acting as catalysts for change, these engineers set in motion a cycle of innovation that drives sustainable growth.

The second role involves being collaborators and enablers. Entrepreneurial engineers understand the value of collaboration and actively seek out partnerships and alliances to bring their innovations to life. They collaborate with other experts, entrepreneurs, industry stakeholders, and even policymakers to leverage collective knowledge, resources, and networks. By fostering collaboration, they create an enabling environment that allows for the effective implementation and scaling of sustainable solutions. Their ability to build bridges between different stakeholders and align their interests further accelerates the adoption of sustainable practices.

Lastly, entrepreneurial engineers take on the role of advocates and ambassadors. They recognize the importance of raising awareness about the benefits of sustainable development and actively promote its adoption within industries (Bugaian, 2022). Through their expertise and persuasive communication skills, they effectively communicate the advantages of sustainable practices to stakeholders, decision-makers, and the general public. By acting as ambassadors for sustainable development, these engineers play a vital role in shaping attitudes, policies, and practices within industries, driving a collective commitment towards sustainability.

Overall, the multifaceted roles played by entrepreneurial engineers significantly contribute to the promotion of sustainable development in modern industry (Raveendra and Rizwana, 2022). Their ability to initiate innovation, collaborate effectively, and advocate for sustainable practices positions them as key drivers of change. By embracing these roles, entrepreneurial engineers pave the way for a more sustainable and prosperous future for industries and society as a whole.

Entrepreneurial computer engineers combine the realms of business and computer engineering, creating a powerful synergy that enhances their capacity to drive innovation within a sustainable ecosystem. By leveraging technological advancements in the entrepreneurial domain, these engineers possess a unique ability to expedite the digital innovation process (Yoo *et al*., 2010). This integrated approach, as described by Van de Ven (1993) and Malecki (2018), not only fuels innovation but also fosters economic growth by contributing to the development of industries.

The integration of business and computer engineering empowers entrepreneurial engineers to navigate the intersection of technology and commerce. Through their comprehensive understanding of both fields, they can identify opportunities for innovation and leverage technological advancements to their advantage. This amalgamation of expertise allows them to swiftly translate ideas into tangible solutions, driving the innovation process forward.

In an innovation ecosystem, the contributions of entrepreneurial engineers are instrumental in shaping industries and propelling economic growth. As highlighted by Audretsch et al. (2019), their innovative endeavors have a profound impact on industry development. By introducing novel products, services, and business models, entrepreneurial engineers fuel the growth and competitiveness of industries, ultimately driving economic progress.

In the pursuit of sustainable development within the innovation ecosystem, dynamic capabilities have emerged as a critical factor. These capabilities encompass the capacity to adapt, innovate, and leverage technological advancements effectively (Teece, 2007; Helfat and Peteraf, 2003). Consequently, entrepreneurs who possess the aptitude for technological innovation have gained prominence.

Discussion and Conclusion

The primary objective of this article is to thoroughly examine the existing body of literature on entrepreneurial computer engineers and their role within the innovation ecosystem. The intention is to provide researchers with valuable insights that can contribute to the advancement of entrepreneurship and ultimately foster a greater number of entrepreneurial engineers. Among the various categories of entrepreneurs, entrepreneurial engineers hold significant influence and potential. Their unique blend of technical expertise and entrepreneurial mindset positions them as key drivers of sustainable development through technological innovation. By leveraging their knowledge and skills in engineering, coupled with their entrepreneurial spirit, these individuals possess the capacity to propel economic progress while addressing the challenges of sustainability.

For this reason, the emergence of entrepreneurial engineers who have a closer relationship with digital technologies are of great importance to accelerate economic development, as Giones and Brem (2017) have shown in their research (Giones and Brem, 2017). The findings of this article demonstrate that entrepreneurial computer engineers play an influential role in guiding organizational digitalization and adapting to emerging technologies through computer-based technological entrepreneurship. This knowledge map governing entrepreneurial engineering highlights their capacity to drive digital transformation within organizations (Bailetti, 2012).

A key focus is to highlight the importance of scientific research in promoting the development of entrepreneurs, particularly among computer engineers. By conducting rigorous scientific investigations, researchers can shed light on the specific skills and competencies that entrepreneurial engineers possess, which are crucial in effectively training and preparing them for success. Furthermore, it is imperative to explore various other engineering disciplines in relation to entrepreneurship. This exploration allows for a broader understanding of the entrepreneurial landscape and facilitates the examination of dynamic capabilities within these specific entrepreneurial types. By understanding and adapting to the intricate complexities inherent in the economy, these entrepreneurial engineers can better navigate and thrive in their respective fields.

"Ideas are implemented in real world with design and engineering"

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