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Mapping the global trends of innovation consciousness: Hotspots and interdisciplinary insights

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Abstract

This study aims to map the global trends of innovation consciousness, exploring its interdisciplinary intersections, research hotspots, and frontier issues from 2014 to 2024. The purpose is to provide a comprehensive understanding of the evolving landscape of innovation consciousness and to identify key research directions. The study employs bibliometric methods using the Web of Science database, with a total of 911 relevant publications selected for analysis. Tools such as CiteSpace and ArcGIS were utilized to conduct a variety of analyses, including keyword co-occurrence analysis, burst term analysis, journal dual-map overlay, national collaboration network analysis, and clustering analysis. This mixed-methods approach allows for a robust examination of the global research trends in innovation consciousness. The analysis reveals that education, management, technology, and creativity are the core research areas in the field of innovation consciousness. Developed countries focus primarily on technology-driven innovation practices and sustainable development, while developing countries place greater emphasis on enhancing innovation consciousness through educational initiatives. The study also identifies emerging trends in digital education platforms, sustainable innovation, compliance, and the integration of smart cities with social innovation. The study provides a clear understanding of the current state and future directions of innovation consciousness research. It highlights the key disciplinary intersections and the varying priorities between developed and developing countries. Despite the identification of several promising research areas, there is a need for further empirical studies to deepen the understanding and practical application of innovation consciousness. The findings offer valuable insights for policymakers, educational institutions, businesses, and researchers. They can guide future research agendas, inform educational strategies, and support the development of policies that foster innovation consciousness at global, regional, and local levels.

Keywords: Bibliometric analysis, Economic development, Innovation consciousness, Innovation education, Sustainable development.

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1. Introduction

In the context of rapid globalization and technological advancements, innovation has become the core driver of socio-economic development [1, 2]. Particularly since the onset of the 21st century, emerging technologies represented by Industry 4.0, artificial intelligence, and digital technology have risen swiftly, significantly altering traditional industries and societal organizational structures [3]. Industry 4.0, through intelligent manufacturing and digital transformation, has driven deep integration and innovation across various industries, while artificial intelligence and digital technology have provided strong technical support for this process [4, 5]. In this broad context, innovation consciousness, as an intrinsic driver of innovation, has become increasingly important [6, 7]. It involves not only the acceptance and application of new technologies and ideas by individuals or organizations but also the realization of broader social change and economic growth through these emerging technologies [8].

The United Nations Sustainable Development Goals (SDGs), particularly Goal 9, emphasize the importance of promoting innovation through inclusive and sustainable industrialization [9]. In this process, cultivating and enhancing innovation consciousness is one of the key factors in achieving these goals. Goal 9.b further suggests supporting domestic technology development, research, and innovation in developing countries to ensure a policy environment conducive to industrial diversification and value addition, which undoubtedly requires a foundation of innovation consciousness [10]. By strengthening innovation consciousness, individuals and organizations can more effectively integrate frontier technologies such as Industry 4.0, artificial intelligence, and digital technology into production and daily life, achieving deep integration of technology and society, and promoting sustainable economic and social development.

However, developed and developing countries face different challenges and opportunities in promoting innovation consciousness [11]. Developed countries, relying on their robust research infrastructure, abundant funding, and mature market mechanisms, can better translate innovation consciousness into technological breakthroughs and market advantages [12]. For instance, the United States, through the support of agencies such as the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (DARPA), has driven disruptive innovations in fields such as information technology and biotechnology [13]. Meanwhile, the European Union, through research initiatives like "Horizon Europe," is committed to leading global innovation trends in digitalization and the green economy [14]. In contrast, although developing countries may lack resources, technological accumulation, and market maturity, they have shown great innovation potential through active policy interventions and international cooperation [15]. Countries such as China and India, for example, have enhanced their innovation consciousness levels and gained increasing significance in the global innovation system by strengthening education and training, promoting the commercialization of scientific research, and fostering entrepreneurship and business incubators [16-18]. Additionally, international organizations such as the World Bank and the United Nations Development Programme (UNDP) have supported many developing countries in achieving technological breakthroughs and industrial upgrades in specific fields through financial and technical assistance [19].

Simultaneously, innovation consciousness plays a critical role not only in economic and educational domains but also in driving social innovation [20]. Social innovation emphasizes addressing social problems through new methods and strategies to promote inclusive and sustainable development [21]. Innovation consciousness encourages individuals and organizations to seek solutions in a more open and creative manner when facing complex and diverse social challenges [22]. For instance, in addressing global issues such as climate change, public health crises, and income inequality, social innovations driven by innovation consciousness provide new approaches to these challenges, thereby advancing overall societal progress [23].

However, despite the broad academic interest in innovation, research on the concept of "innovation consciousness" is still limited. While studies on organizational innovation (Bayne et al. [24]), creativity (Seth and Bayne [25]), and sustainable innovation (Sarasso et al. [26]) provide valuable insights into global innovation trends, they mainly focus on bibliometric analysis without delving deeper into the underlying factors driving innovation. Furthermore, few studies have explored the concept of "innovation consciousness" itself. This research aims to bridge this gap by adopting an interdisciplinary perspective, integrating views from management, education, sociology, and other disciplines, and utilizing statistical methods to examine the evolution of innovation consciousness from a global perspective.

Based on this, the present study aims to conduct a bibliometric analysis of literature related to "innovation consciousness," "conscious innovation," and "innovative thinking" published between August 1, 2014, and August 1, 2024. This study systematically reviews and explores research developments, frontier dynamics, and key issues in this field.

Through visual analysis using tools like CiteSpace and ArcGIS, this research not only reveals the global evolution trends in innovation consciousness research but also elucidates the paths and experiences of different countries and regions in cultivating and developing innovation consciousness by interpreting maps of keyword co-occurrence, national collaboration networks, and more. This study will provide policymakers, academia, and industry with deeper and broader references to further promote the application and dissemination of innovation consciousness in social development. Specifically, this research seeks to address the following research questions:

1) What are the main development trends and interdisciplinary intersections of 'innovation consciousness' research globally from 2014 to 2024?

2) What are the key differences and commonalities between developed and developing countries in promoting 'innovation consciousness' research and practice?

3) What are the research hotspots and frontier issues in the field of 'innovation consciousness'?

What might be the future directions of research in this area? The structure of this paper is as follows: Section 2 presents a literature review on innovation consciousness and its intersections with related fields. Section 3 outlines the research methodology used for the bibliometric analysis, especially the tools: the use of CiteSpace and ArcGIS. Section 4 presents the results and discussions based on the visualization maps generated from the bibliometric data. Finally, Section 5 concludes with key insights and policy recommendations for advancing innovation consciousness in the global context.

2. Literature Review

Consciousness is a complex concept, defined as the psychological perception and intentional behavior controlled by the human brain [24-26]. Innovation, on the other hand, refers to the ways in which individuals generate ideas and solve problems, as well as the extent to which an individual or group adopts new ideas, technologies, and innovations earlier than other members of a social system [27, 28]. Based on these definitions, innovation consciousness can be defined as the degree of awareness and integration of new technologies and ideas that drive innovation and creativity. Innovation consciousness can also be understood as conscious innovation, which is a method that combines future thinking and systems thinking, aiming to promote long-term reflection, personal transformation, creative problem-solving, and thoughtful adaptation and collaboration to address complex challenges Cabrera and Cabrera [29]; Olimov [30] and Musaeva [31]. Schwartz [32] synthesized a decade of research on creativity, describing historically notable creative individuals and suggesting that understanding the relationship between creativity, intuition, and innovation can inspire moments of genius, ultimately leading to better, more insightful researchers, clinicians, and businesspeople.

In the field of education, the role of cultivating innovation consciousness in improving educational quality has become increasingly evident [33-35]. Bibliometric analysis shows that the number of studies on this topic has increased annually in recent years, with significant progress in understanding how education can enhance students' innovation capabilities. Olugbara et al. [36] found that pre-service teachers' innovation consciousness significantly enhances their learning intentions and behaviors in an e-learning context, providing valuable insights for education policymakers. Additionally, Zhao et al. [37] and Wang [38] emphasized that higher education institutions must adapt to the demands of the digital economy by enhancing the innovativeness of educational content and methods to foster students' innovation consciousness. Bosman and Eom [39] conducted a qualitative study using NVivo, integrating an innovation thinking framework into undergraduate interdisciplinary engineering and technology courses to explore new product development in food science and technology. Zhou [40], in his study on computer science students at a technical university, discussed methods and strategies for reforming computer network courses, highlighting the need for universities to continually shift their thinking and actively apply innovation thinking and conscious innovation to update teaching content and improve teaching systems. For students, utilizing technology and innovation is crucial as it not only helps them learn and understand technical skills but also enables them to identify problems, find solutions, and communicate value propositions [41].

On the other hand, from the perspective of social development, innovation consciousness and innovation thinking have also garnered increasing attention [42-44]. The ability to generate innovative and entrepreneurial ecosystems is a key component of any organization's survival and longevity [45]. By addressing decision-making and projects from a perspective of conscious evolution, institutions can find sustainable solutions Pizana et al. [46]. Yu and Li [47] conducted a comprehensive review of Chinese enterprises and found that, in the context of rapid productivity growth during the Fourth Industrial Revolution, as key members of the national innovation system, enterprises must incorporate innovation consciousness into corporate transformation to stimulate sustainable economic performance. Deniz [48] proposed that creating sustainable solutions for cities requires combining social innovation with sustainable design thinking and changing culture through innovation consciousness and innovation thinking, whether from the top down or bottom up, ultimately leading to successful innovative solutions. Cunha et al. [49], through case studies, further emphasized the importance of conscious innovation in fostering social innovation in response to the challenges brought about by the digitalization process under the backdrop of Industry 4.0. Asmaraningtyas et al. [50] started from innovation thinking with social innovation as the goal, integrated sustainability and Islamic business ethics values into creating a green business model that is not only competitive but also sustainable in ecological, social, and economic terms. It is evident that enterprises, driven by innovation willingness, need to integrate innovation motivation, innovation capabilities, and innovation resources, and use appropriate innovation mechanisms to overcome innovation biases, thereby stimulating sustainable economic performance to address issues in the innovation chain such as innovation motivation, innovation capabilities, innovation resources, innovation security, and innovation bias [51, 52].

Based on this, this study, through bibliometric analysis, can deeply reveal the research hotspots and frontier issues in this field, providing researchers with a macro perspective that not only deepens the theoretical understanding of innovation

consciousness but also lays a solid foundation for analyzing interdisciplinary research trends. This analytical approach not only aids in a comprehensive understanding of the core role of innovation consciousness in social change and educational reform but also provides a scientific basis for predicting future research directions and formulating innovation strategies.

3. Research Methodology

This study uses bibliometric analysis to explore the development, frontiers, and hotspots in the field of "innovation consciousness." Bibliometric methods, which analyze academic literature through statistical tools, are widely used to identify research patterns and trends [53]. Unlike traditional reviews, this study relies on quantitative data from databases like Web of Science (WoS), providing a comprehensive and objective overview of the field [54].

Data were collected from WoS, covering the period from August 1, 2014, to August 1, 2024. This timeframe ensures the inclusion of the latest research on innovation consciousness. Advanced visualization tools such as CiteSpace and ArcGIS were used for keyword co-occurrence, burst terms, journal dual-map overlay, national collaboration networks, and clustering analysis. These tools help map research evolution, identify clusters, and highlight global collaboration.

This study differs from past research by focusing specifically on innovation consciousness and using an interdisciplinary approach, integrating insights from management, education, and sociology. While previous studies often limited themselves to basic bibliometric counts, this study uncovers deeper connections and trends through advanced analytical techniques, providing a more holistic view of the field.

3.1. Literature Search Strategy

In the initial search phase, we used "innovation consciousness" as a keyword, which yielded only 20 relevant publications. To expand the data scope and conduct a more in-depth analysis of this complex concept, we further defined "innovation consciousness" as "conscious innovation," which refers to the degree of awareness and creativity involved in integrating new technologies and ideas for innovation [26-28]. Based on this definition, the study utilized the terms "innovation consciousness," "conscious innovation," or "innovative thinking" as the subject keywords for the search. As a result, the number of retrieved documents significantly increased, totaling 911 publications.

3.2. Data Screening and Processing

For the 911 retrieved publications, according to Arokiasamy et al. [55], the research team carefully reviewed the titles and abstracts of each to ensure their relevance to the theme of "innovation consciousness." Since all the documents aligned with the research theme, no articles were excluded. The literature data were downloaded in "plain text format" and imported into CiteSpace 6.1.R6 for subsequent analysis. Additionally, ArcGIS was employed for the geographical visualization of the data to further deepen the study.

3.3. Bibliometric Analysis Tools and Techniques

This study primarily utilized two tools, CiteSpace 6.1. R6 and ArcGIS, for data analysis and visualization. CiteSpace 6.1. R6, as a crucial tool for bibliometric analysis, assisted in the creation and examination of the following key visualizations:

Journal Dual-Map Overlay: Used to identify and compare the influence and research developments of different journals within the "innovation consciousness" field.

- Keyword Co-Occurrence Analysis: Reveals the relationships between research hotspots and core concepts.
- National Collaboration Network Co-Occurrence: This illustrates the research collaboration relationships between different countries and the structure of international cooperation networks.
- National Publication Data Map: Created using ArcGIS, this map displays the distribution of research outcomes in the field of "innovation consciousness" across various countries.
- Keyword Clustering Analysis: Identified the main research themes within the field and their evolutionary trends.
- Keyword Timeline and Time-Zone Maps: Helped in understanding the evolution paths of keywords and the research focus during different time periods.
- Burst Term Analysis: Used to identify significant concepts or themes that emerged suddenly during specific time periods, highlighting the frontier dynamics of the research.

4. Results and Discussion of the Bibliometric Analysis

4.1. Regional Distribution and Collaborative Network Analysis of Global Innovation Consciousness Research

To delve into the major differences and commonalities among countries in promoting research and practice in "innovation consciousness" on a global scale, this study utilized CiteSpace, supplemented by Excel and ArcGIS, to create visual maps (as shown in Figures 1-3). These visualizations reveal the performance and development trends of different economies within this field.

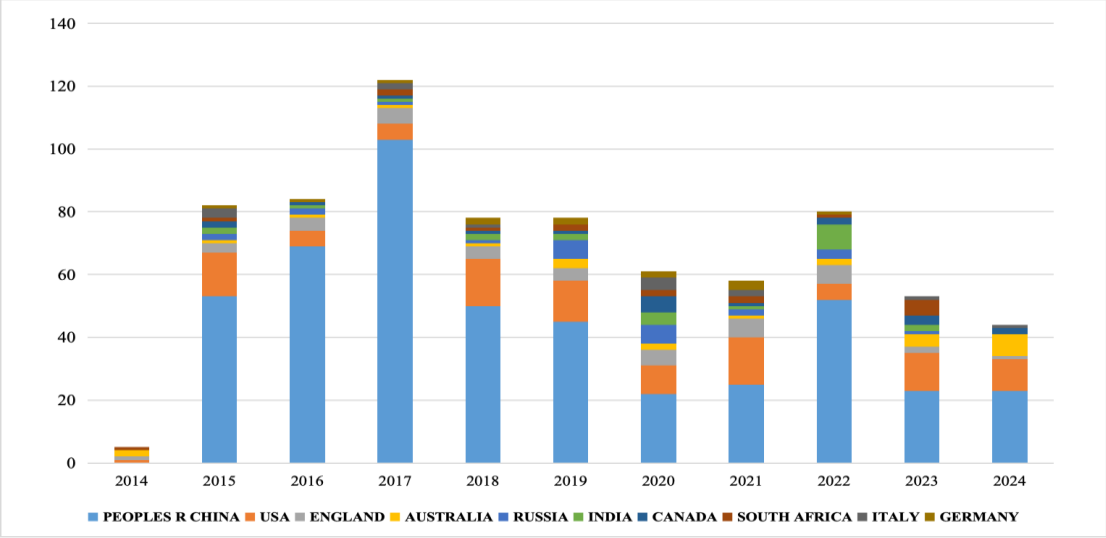

Figure 1.
Number of publications by country.

Figure 1 illustrates the top ten countries in terms of the number of publications in the field of "innovation consciousness" from 2014 to 2024. The data shows that China began to engage in this field of research in 2015 and quickly emerged as a dominant force. Specifically, China published 53 related articles in 2015, reaching a peak in 2017 with 103 publications. In 2015, the Chinese government launched the "Innovation-Driven Development Strategy" and the "Mass Entrepreneurship and Innovation" policies, which significantly boosted nationwide technological innovation activities and directly contributed to the flourishing of research related to innovation consciousness [56]. With the continued investment in innovation resources and the deepening reform of the science and technology system, China's innovation efficiency is expected to further improve, and the country's comprehensive national innovation capacity ranking will steadily advance towards the ranks of innovation-driven nations [57]. This indicates that, driven by national policies, China has rapidly secured an important position in global innovation research. The publication volume in the United States remained stable throughout the decade, with an average of 10 publications per year. Although the growth in the U.S. publication volume was not as dramatic as China's, its consistent research output underscores its sustained contribution to this field. As a global leader in technological innovation, the United States, supported by its robust research infrastructure and strong research teams, is expected to continue playing a pivotal role in the field of innovation consciousness [53].

Countries such as the United Kingdom, Australia, Russia, and India have relatively fewer publications, but the increasing trend in their output indicates a growing attention to innovation consciousness research. Notably, the United Kingdom and Australia, despite having lower publication volumes, have shown a gradual increase in annual research outcomes, reflecting their steadily rising academic influence in this area.

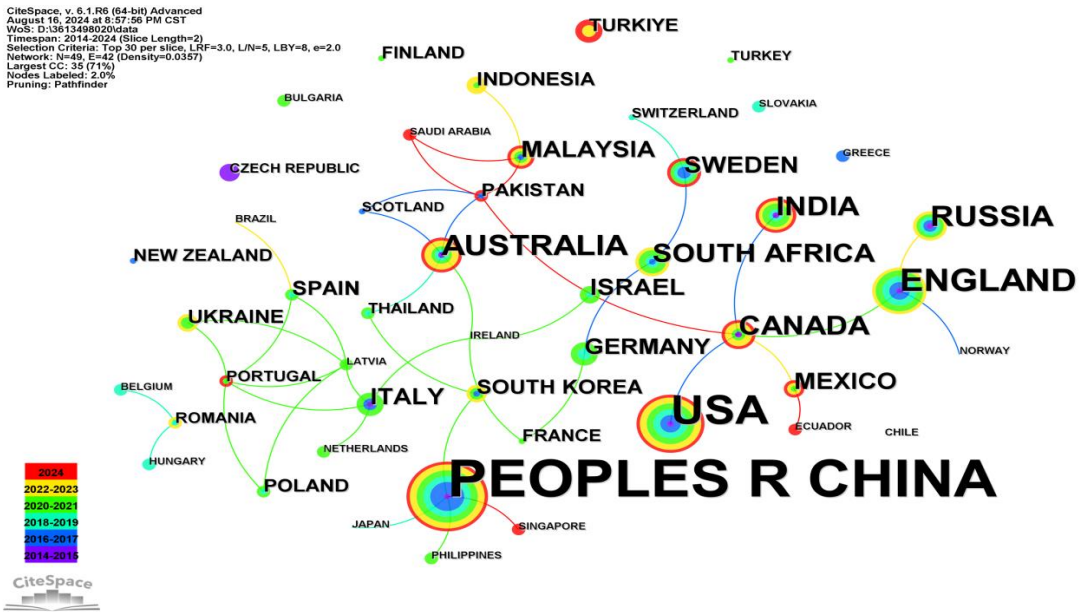

Figure 2.
Visualization map of national co-occurrence.

Further exploring the key differences and commonalities between developed and developing countries in promoting research and practice in "innovation consciousness," Figure 2 presents the international collaboration network from 2014 to 2024. This figure reveals the performance and development trends of different economies within this field. Over the decade, a total of 49 countries (N=49) participated in research on "innovation consciousness," with 42 instances of international collaboration (E=42). Network density, which is an indicator used to represent the strength of connections between nodes in a network, shows that the higher the density, the tighter the connections between nodes [54]. The network density in the national collaboration co-occurrence network is 0.0357 (density=0.0357), indicating that global cooperation in the field of innovation consciousness research is relatively loose, with a relaxed international collaboration network. This suggests that research connections between countries are limited, with collaboration mainly concentrated among a few core countries. To enhance the overall level of research, it is recommended to strengthen cross-national collaborations, fostering broader international scientific cooperation to increase network density and the global influence of innovation research.

In conjunction with the data presented in Table 1, it is evident that between 2014 and 2024, China led the world with 465 publications, far surpassing the United States with 104 publications and the United Kingdom with 41. Other countries with relatively high publication volumes include Australia (25 publications), Russia (24 publications), and India (23 publications). Notably, although China first published related literature in 2015, it quickly became a leader in this field within just a few years. This rapid ascension reflects China's emergence as a significant force in global innovation research, driven by national policies [57]. While the United States ranks second to China in publication volume, it plays a pivotal role as a central node in the global scientific collaboration network. Other countries, such as the United Kingdom, Australia, Canada, and Germany, also show high centrality in the collaboration network, indicating that these countries not only have substantial research output but also hold key positions in international collaborations.

Table 1.
Statistics of the top 20 countries for article publication from 2014 to 2024.

Country	Year of first publication	Centrality	Frequency
CHINA	2015	0.17	465
USA	2014	0	104
ENGLAND	2014	0.12	41
AUSTRALIA	2014	0.64	25
RUSSIA	2015	0	24
INDIA	2015	0	23
CANADA	2015	0.37	19
SOUTH AFRICA	2014	0.11	17
ITALY	2015	0.35	14
GERMANY	2016	0.16	13
MALAYSIA	2017	0.06	12
ISRAEL	2019	0	11
SWEDEN	2016	0.06	11
MEXICO	2020	0.06	11
SPAIN	2019	0.06	8
SOUTH KOREA	2014	0.21	8
INDONESIA	2021	0	7
UKRAINE	2020	0	7
PAKISTAN	2017	0.49	6
TURKIYE	2023	0	6

Utilizing the data discussed above, Figure 3 presents a geographic map of global scientific outputs generated using ArcGIS. Overall, the map illustrates that developed countries, with their robust research infrastructure and multilateral collaborations, continue to dominate global innovation research, while developing countries are gradually enhancing their influence through active participation in international collaborations [58, 59].

Developed countries, such as the United States and European Union member states, have steered the global direction of innovation research by leveraging their strong research infrastructure, abundant innovation resources, and well-established policy frameworks [60]. In 2024, the United States, through its "National Strategy for Inclusive Innovation,"[1] emphasized broad participation in science, technology, engineering, and mathematics (STEM) fields, as well as in invention and innovation, to drive economic growth, create high-quality jobs, and address global challenges. Similarly, the "2024 European Innovation Scoreboard"[2] highlighted an overall improvement in innovation performance among EU member states, particularly in Denmark and Sweden. However, the EU faces challenges in the global innovation system, particularly in intellectual assets and small- to medium-sized enterprise (SME) cooperation, prompting calls for strengthened internal and external strategic cooperation to maintain its competitive edge against the United States and China.

[1] The U.S. Patent and Trademark Office (USPTO), https://www.uspto.gov/initiatives/equity/national-strategy-inclusive-innovation
[2] European innovation scoreboard 2024, https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en

In contrast, developing countries like China, India, and South Africa have gradually increased their influence in the field of innovation consciousness through policy-driven initiatives and international cooperation. China has risen rapidly as a major research force since entering the field in 2015. In 2024, the Chinese government launched the "New Quality Productivity"[3] strategy, which promoted innovation research in frontier areas such as digital technology and green energy [61]. Additionally, China has leveraged "The Belt and Road Initiative"[4] to strengthen scientific collaboration with ASEAN countries and other global partners [62]. This strategy has bolstered China's influence within the global innovation network and facilitated greater international collaboration, thereby advancing global research on innovation consciousness. However, significant gaps remain between developing and developed countries in terms of research capacity, international influence, and the ability to integrate innovation resources [63].

Despite these differences, there are notable commonalities between developed and developing countries in their approach to global innovation collaboration. Both groups recognize the importance of transnational cooperation in addressing global challenges and have, on this basis, established extensive collaborative networks that have driven the in-depth development of innovation consciousness research worldwide. This has fostered an interdependent relationship within the global innovation ecosystem [64].

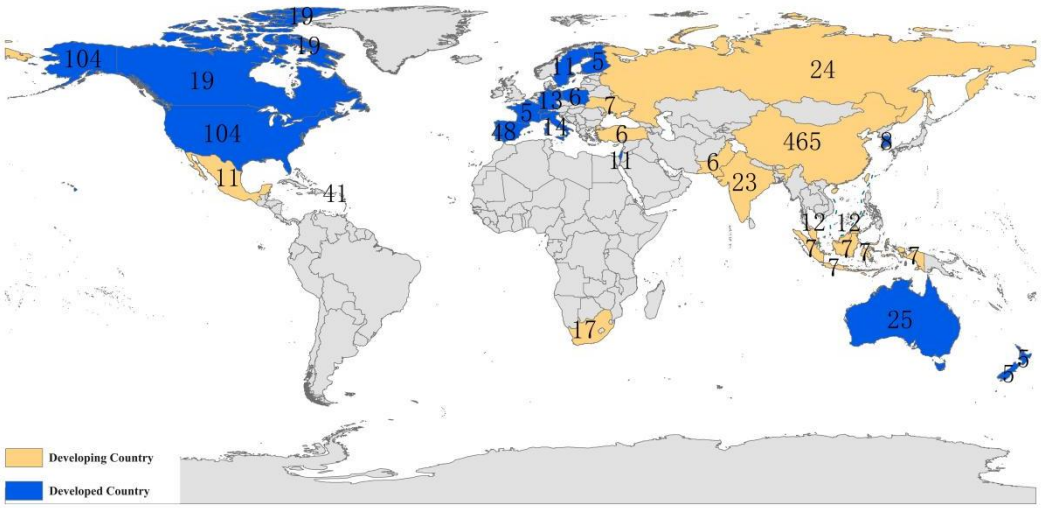

Figure 3.
Geographical map of the world's scientific achievements.

4.2. Analysis and Discussion of Knowledge Frontiers, Foundations, and Interdisciplinary Connections in the Field of Innovation Consciousness

Exploring interdisciplinary connections within the field of "innovation consciousness" is crucial for understanding the development of this area. As shown in Figure 4, research in the "innovation consciousness" field is highly concentrated in disciplines related to education and social sciences. Specifically, education and educational research constitute 29.1% of the total, highlighting the central role of education in advancing research on innovation consciousness. Interdisciplinary social science research follows closely, occupying 16.0%, indicating that social sciences provide significant theoretical support for understanding and developing innovation consciousness in interdisciplinary studies. Management studies, accounting for 11.9%, rank third, reflecting the importance of management practices in innovation consciousness research, especially in the context of integrating management with innovation practices within organizations.

Additionally, computer science and engineering-related fields also hold a significant proportion, demonstrating a growing trend in technology-driven innovation consciousness research. Other areas, such as environmental science, psychology, and multidisciplinary sciences, also exhibit some degree of intersectionality, indicating the broad application of innovation consciousness research in addressing complex social issues and fostering interdisciplinary integration.

This distribution underscores the multidisciplinary nature of innovation consciousness research, emphasizing the importance of cross-disciplinary collaboration in understanding and advancing this field. As innovation consciousness continues to develop, the convergence of different disciplines will likely play an increasingly vital role in generating new insights and practical applications.

3 people's government of the people's republic of China, accelerating the cultivation and development of new quality productive forces, https://www.gov.cn/yaowen/liebiao/202407/content_6964160.htm
4 BELT AND ROAD PORTAL, The Belt and Road Initiative, https://eng.yidaiyilu.gov.cn/

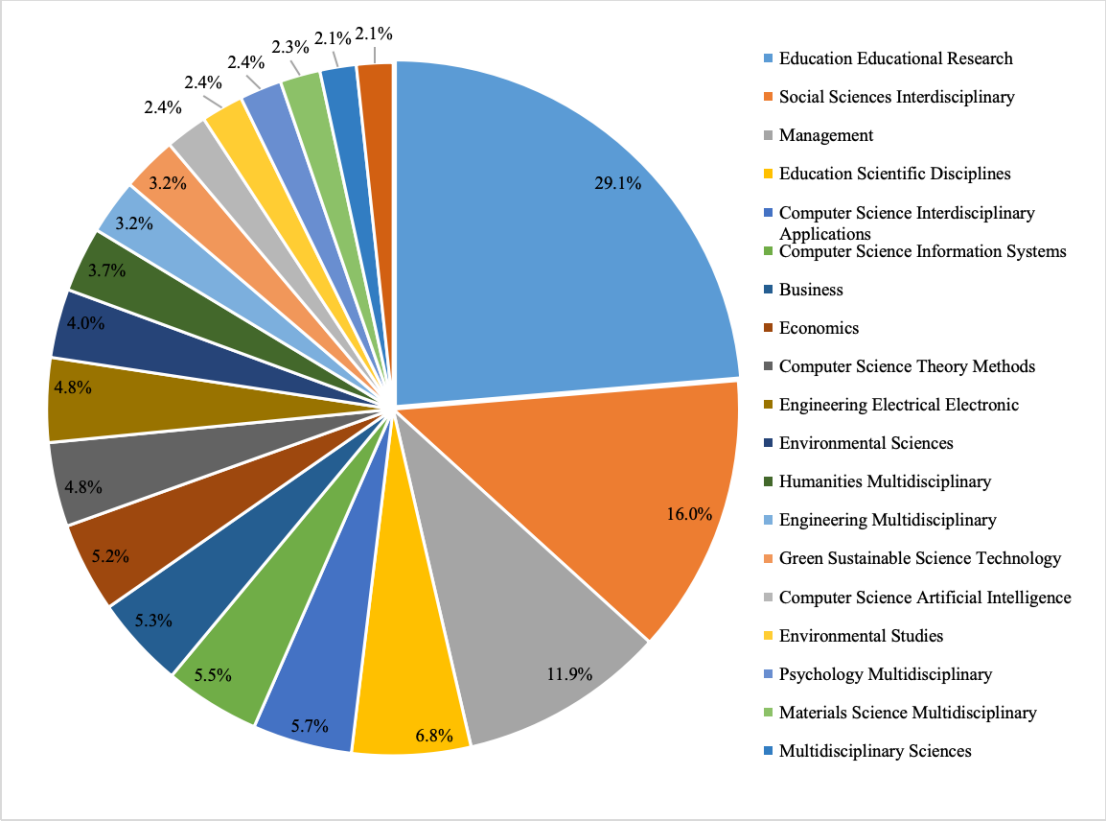

Figure 4.
Statistics of the subject areas of the journals in which the articles were published.

To further unveil the interdisciplinary connections and developmental pathways within the field of “innovation consciousness” research, a journal dual map overlay visualization was created using CiteSpace, as shown in Figure 5. The journal dual-map overlay is a powerful tool that helps researchers understand the knowledge frontiers and foundational structures of a field by displaying citing and cited maps [65].

The citing map on the left side illustrates the knowledge frontiers in current research within the "innovation consciousness" field. The different colored dots represent journals from various research domains. The citing map highlights the multidisciplinary nature of "innovation consciousness" research, with fields such as computer science, engineering, management, and education prominently represented. Notably, journals in the fields of computer science and engineering frequently publish the latest research findings due to their focus on technological innovation and applied research, making them key drivers in the development of innovation consciousness. Meanwhile, journals in the management and education fields focus on how to integrate innovation consciousness into management practices and educational systems, reflecting a trend where knowledge frontiers are increasingly transitioning towards practical applications.

The cited map on the right side reveals the knowledge base of the "innovation consciousness" field, i.e., the body of literature that current research frequently cites. The ellipses in the map represent the influence of these foundational studies. A longer vertical axis indicates a higher volume of published papers in a particular journal, reflecting its high level of activity in current research. A longer horizontal axis suggests a broad author base, indicating a diverse group of contributors in the field [65]. The presence of large ellipses on the cited map often corresponds to well-established journals that have accumulated significant scholarly contributions over time, providing a solid theoretical and practical foundation for research in "innovation consciousness." For example, management and education journals are heavily cited, underscoring the importance of these fields in supporting current innovation consciousness research. Additionally, journals in social sciences and computer sciences also hold prominent positions on the cited map, highlighting the critical role of these disciplines' theories and methodologies in understanding and advancing innovation consciousness.

The citation links between the citing and cited maps are crucial for understanding the relationship between knowledge frontiers and their foundations. These links represent citation relationships between current research and existing knowledge, illustrating the pathways of knowledge flow [65]. The *Z*-Scores function highlights stronger and more fluid citation trajectories, with the thickness of cyan lines indicating the strength of knowledge transmission. The thickest line connects fields that reflect the depth and breadth of interdisciplinary interactions. Foundational disciplines such as psychology, education, economics, and political policy continue to provide theoretical support and methodological innovation for frontier research in health, education, psychology, and economics. This knowledge transmission pathway suggests that current research in innovation consciousness increasingly relies on interdisciplinary collaboration, particularly when addressing complex social issues and global challenges. The integration of knowledge from different fields has become a crucial force driving research progress.

Notably, education, psychology, and economics have consistently played pivotal roles in the research of "innovation consciousness." Psychology offers profound insights into individual and collective behaviors during the innovation process, especially in areas related to behavior, cognition, and motivation, which are critical for the formation and implementation of innovation [66]. Education lays the foundation for cultivating and disseminating innovation consciousness, providing theoretical support for enhancing innovation capabilities within educational systems and, consequently, raising the overall innovation level of society [67]. Economics plays a crucial role in understanding innovation-driven economic development and policy impacts, offering theoretical frameworks to explain the effects of innovation on economic growth and market dynamics [68]. The interaction of these disciplines collectively forms the multidimensional foundation that drives innovation consciousness research forward.

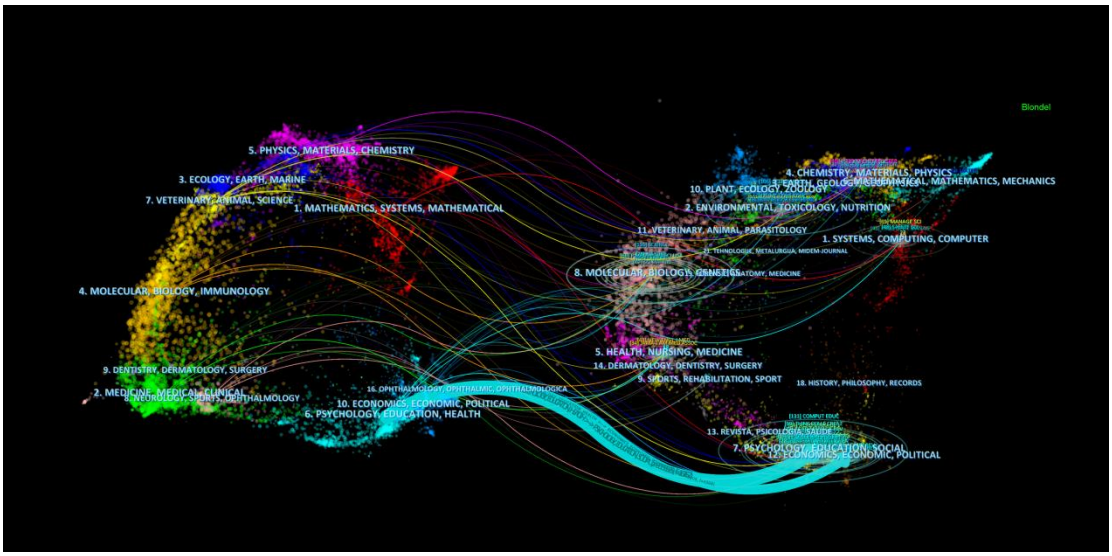

Figure 5.
Journal double chart overlay to explore research frontiers and foundations.

4.3 Analysis and Discussion of Research Development and Hotspots in the Field of Innovation Consciousness

As shown in Figure 6, the keyword co-occurrence map provides a panoramic view of the relationships between different themes in the field of "innovation consciousness" research. Each node in the map represents a keyword (N=73), with the size of the node indicating the frequency of that keyword's appearance in relevant studies. The lines between the nodes represent co-occurrence relationships (E=103), showing how often these keywords are mentioned together in the same research.

In this visualization, keywords such as "innovative thinking," "management," "creativity," and "higher education" occupy central positions, indicating that these themes are core areas of focus within innovation consciousness research. The prominence of these core areas not only reflects the primary concerns of the academic community but also underscores important trends in policy implementation and social practice across various countries. Innovative thinking serves as the foundation for driving innovation within individuals and organizations, emphasizing the importance of breaking conventional thinking patterns to explore new solutions [69]. The European Union, through its "Horizon 2020" [5] the program has emphasized the cultivation of interdisciplinary collaboration and innovative thinking to promote cooperation among member states in research and technological innovation, ultimately contributing to the achievement of sustainable development goals.

The role of "management" in the innovation process is also crucial, involving the effective allocation of resources, incentivizing innovative behavior, and protecting intellectual property [70]. In the United States, innovation management is widely practiced, particularly in innovation hubs like Silicon Valley, where venture capital, intellectual property protection, and the construction of innovation ecosystems have driven global innovation [71]. "Creativity" is the core driving force behind transforming novel ideas into practical applications [72]. Creativity education is widely applied within school systems, encouraging students to engage in innovative experiments in both technological and artistic fields. This bottom-up innovation culture has helped drive the continuous iteration and optimization of technological outcomes [73]. "Higher education" plays a critical role in cultivating innovative talent and advancing technological progress. Under China's strategy of innovation-driven development, the country continues to promote strategies for becoming a talent powerhouse and an educational stronghold. By integrating innovation and entrepreneurship education into higher education institutions, China fosters the commercialization of scientific and technological achievements, thus promoting social innovation [74].

Additionally, other significant keywords such as "student," "performance," "design," and "strategy" further highlight the broad application and focus on innovation consciousness within education, management, and technological innovation. These keywords collectively outline the primary hotspots in "innovation consciousness" research, involving multidimensional exploration from theory to practice and from education to management.

This analysis underscores the ongoing evolution and diversification of research in innovation consciousness, with increasing emphasis on how different disciplines intersect to address complex, real-world challenges. The identified hotspots reflect

5 Horizon Europe Programme, https://horizon-europe.org.ua/

both the academic focus and practical implications of innovation consciousness, guiding future research and informing policy-making and educational practices.

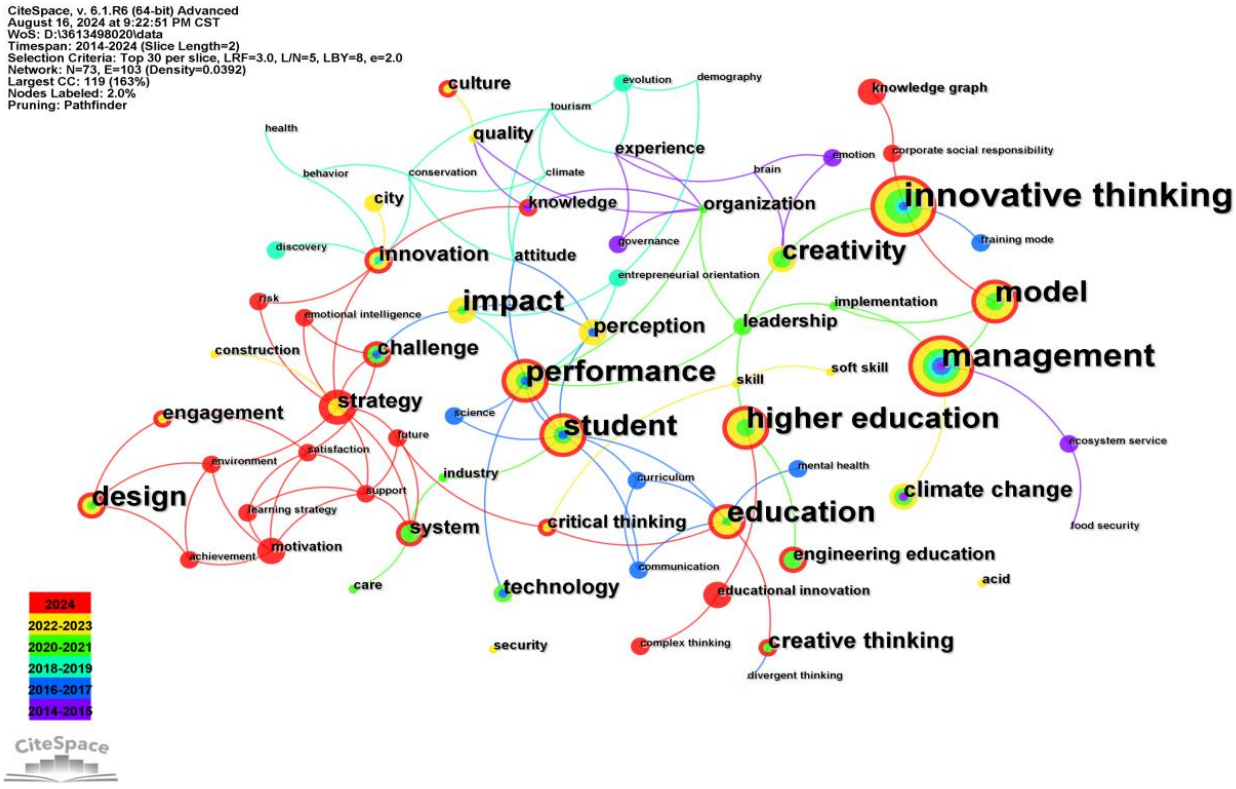

Figure 6.
Keyword co-occurrence network.

To delve deeper into the dynamics of the innovation consciousness field, we incorporated a temporal dimension by slicing the data into two-year intervals and selecting the top 30 most frequently cited or most commonly occurring items. This approach produced a time-zone map of keyword evolution, as shown in Figure 7.

Early Stage (2014-2015): Research during this period primarily focused on fields such as “management,” “creativity,” and “climate change.” These themes reflect the initial characteristics of innovation consciousness research, where scholars concentrated on how management and creativity could drive innovation while also considering the impact of global challenges like climate change on innovation [75, 76].

Mid-Stage (2016-2020): This period marked a significant developmental phase for innovation consciousness research. The studies continued to explore early-stage themes but also introduced new keywords such as “innovative thinking,” “creative thinking,” “divergent thinking,” and “higher education”. It is noteworthy that researchers began to shift from exploring innovation in isolated domains to adopting more integrated approaches, particularly focusing on how the education system could cultivate innovation consciousness [77]. Many countries initiated educational reforms to incorporate innovation and entrepreneurship education into university curricula, aiming to systematically develop students' innovative capabilities [78]. This phase of research heavily relied on foundational theories from psychology, especially in understanding and promoting innovative thinking, creative thinking, and divergent thinking [79]. The interdisciplinary combination of psychology and education significantly advanced the cultivation and development of innovation consciousness.

Recent Years (2021-2024): Research in this period shows further deepening and expansion of the innovation consciousness field. Emerging keywords such as “strategy,” “engagement,” “emotional intelligence,” and “corporate social responsibility” have become research hotspots. During this time, researchers increasingly focused on applying the innovative thinking cultivated through education to the management practices of social organizations and enterprises [80]. The appearance of keywords like strategy and engagement indicates that scholars are exploring how systematic strategic planning and broad organizational participation can drive the actual innovation process. This shift from education to practice suggests that innovation consciousness research has gradually moved from theoretical guidance to practical validation, strengthening the connection between theory and application.

Simultaneously, there has been a growing emphasis on sustainability and social responsibility in recent studies. The emergence of keywords such as corporate social responsibility and emotional intelligence reflects researchers' recognition that innovation should not only aim to enhance technological and economic benefits but also address social and environmental sustainability [45]. This trend highlights the multidimensional nature of modern innovation consciousness research, which seeks to balance technological advancement and economic growth with social responsibility and environmental protection, promoting a more comprehensive and sustainable model of innovation.

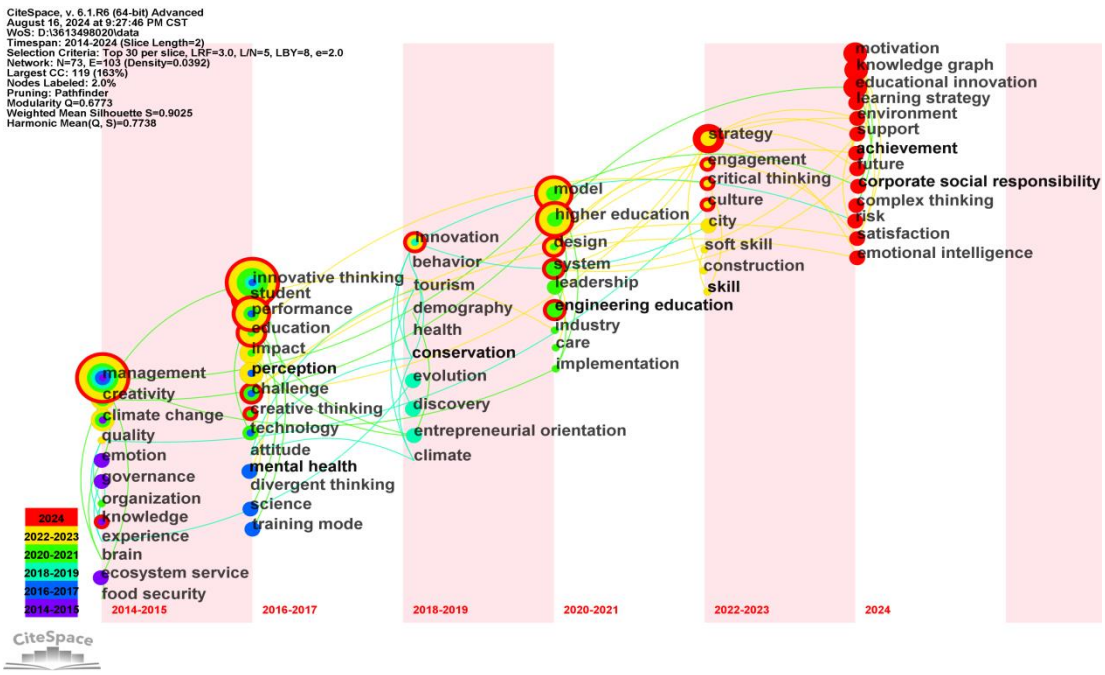

Figure 7.
Keyword evolution time zone chart.

4.4. Exploration of Future Research Directions in the Field of Innovation Consciousness

Building on the keyword co-occurrence and time-zone maps, we conducted a detailed analysis of research within the field of innovation consciousness. High-frequency keywords were clustered, as shown in Table 2. We then utilized CiteSpace to generate a visual map of these clusters, as depicted in Figure 8. Subsequently, the keywords within each cluster were sorted chronologically based on their first appearance year, forming a cluster timeline map, as illustrated in Figure 9. This approach not only helps identify current research hotspots but also reveals the evolutionary trajectory of these hotspots over time, providing critical insights for exploring future research directions.

Table 2.
Clustering module content.

Cluster number	Size	S value	Average Year	Clustering content (LLR algorithm)
#0	15	0.966	2022	MOOCs (8.35, 0.005); sustainability (8.35, 0.005); learning strategies (4.16, 0.05); artificial intelligence (4.16, 0.05); common agricultural policy (cap) (4.16, 0.05)
#1	11	0.933	2018	Laboratory instruction (3.54, 0.1); soft skills (3.54, 0.1); originality (3.54, 0.1); reasoning training (3.54, 0.1); modified task-based learning program (3.54, 0.1)
#2	10	0.823	2018	Psychological interventions (6.32, 0.05); behavioral decision science (6.32, 0.05); vocational education (6.32, 0.05); forest-based tourism (6.32, 0.05); envision rating system (6.32, 0.05)
#3	9	1	2018	Higher education (23.45, 1.0E-4); educational innovation (14.21, 0.001); complex thinking (12.94, 0.001); innovative thinking (11.89, 0.001); 0 (9.68, 0.005)
#4	9	1	2018	Creativity (3.51, 0.1); educational innovation (3.51, 0.1); economic responsibility audit (3.02, 0.1); carrying capacity (3.02, 0.1)
#5	7	0.741	2015	Compliance with guidelines (4.91, 0.05); supply (4.91, 0.05); R&D interest (4.91, 0.05); dental (4.91, 0.05); private actor (4.91, 0.05)
#6	7	0.742	2017	Green innovation (7.64, 0.01); China (4.14, 0.05); medical college students' employability (3.81, 0.1); pollution (3.81, 0.1); trip (3.81, 0.1)

The clustering of high-frequency keywords allows for the identification of distinct research themes within the innovation consciousness field. Each cluster represents a concentrated area of research, where related concepts and methodologies converge [54]. By analyzing the cluster visualization map (Figure 8) and the corresponding timeline (Figure 9), we can trace the development of these themes and observe how certain topics have gained prominence or evolved over time.

This chronological mapping of clusters provides valuable guidance for future research by highlighting emerging areas of interest and potential gaps in the existing literature. It offers a temporal perspective on how innovation consciousness has been studied across different domains and how these studies have responded to shifting societal and technological landscapes.

For instance, if certain clusters have shown rapid growth or sustained relevance over time, they may indicate areas where continued research is likely to yield significant advancements. Conversely, clusters that have seen less attention recently might suggest opportunities for revisiting or expanding upon earlier work, particularly considering new developments or challenges.

Overall, this systematic clustering and chronological analysis serves as a strategic tool for forecasting future research directions in the innovation consciousness field. It helps scholars and practitioners alike to focus on the most promising areas, ensuring that research efforts are aligned with the evolving needs and trends of society.

As shown in Figure 8, seven clusters were generated in the field of innovation consciousness, labeled from #0 to #6. The smaller the number, the more keywords the cluster contains.

Cluster #0: MOOCs highlight the critical role of online education in cultivating innovation consciousness, emerging as a major research hotspot by 2022. Especially during and after the COVID-19 pandemic, MOOCs rapidly became an integral part of higher education. This cluster not only focuses on the widespread adoption of MOOCs as an educational model but also explores how sustainability and artificial intelligence technologies can further optimize and enhance the effectiveness of MOOCs. In practical applications, such as agricultural policy (CAP), MOOCs offer new pathways for interdisciplinary integration and global dissemination of educational resources, promoting a deep integration of educational innovation and industry development. This indicates the significant importance of the ongoing development of digital education in cultivating innovative talent and advancing societal progress [81].

Cluster #1: Laboratory Instruction reflects the importance of hands-on practice and experimentation in developing students' innovative abilities and soft skills. Research indicates that laboratory instruction is not only a platform for applying theoretical knowledge but also a key avenue for fostering originality and reasoning skills in students [82]. This cluster emphasizes the importance of task-based learning plans and soft skill training in modern education. Particularly in fields like science and technology, laboratory instruction has become a core method for promoting innovative thinking and practical abilities. Moreover, innovations and reforms in laboratory instruction hold significant implications for the future of education.

Cluster #2: Psychological Interventions underscores the pivotal role of psychology in enhancing individual and group innovation capabilities. Psychological interventions have significant theoretical importance and are widely applied in vocational education and innovation practices [36]. This cluster covers diverse applications such as behavioral decision science, vocational education, and forest tourism, revealing various ways in which psychological interventions can improve innovation performance. The integration of psychology with practical applications offers new methodological support for innovation education and social practice, further expanding the role of psychological interventions in enhancing overall societal innovation capacity.

Cluster #3: Higher Education delves into the central role of higher education in fostering innovative and complex thinking. Research in this cluster reflects how global higher education systems are enhancing students' practical abilities and theoretical knowledge in innovation through interdisciplinary collaboration and systematic educational reforms. The innovative transformation of higher education focuses not only on knowledge transmission but also on developing students' critical thinking and creativity, addressing the urgent need for innovative talent in future societies [83].

Cluster #4: Creativity explores the dual role of creativity in educational innovation and economic responsibility. Creativity is not only a key element in education but also plays a crucial role in economic responsibility audits and social sustainability [84]. This cluster highlights the deep connection between creativity and socio-economic development, reflecting the need for universities to focus not only on academic quality but also on leading social responsibility and sustainable development efforts through innovative education.

Cluster #5: Compliance with Guidelines emphasizes the importance of compliance in innovation activities, particularly in supply chain management, research and development, and private sector innovation. This cluster demonstrates the critical role of legal and ethical standards in innovation activities, indicating that while advancing technological progress, strict compliance management is essential to ensure the long-term sustainability of innovation efforts [85].

Cluster #6: Green Innovation focuses on innovation research in the context of global sustainable development. This cluster includes studies on China's practices in green innovation, particularly achievements in pollution control, environmental protection, and the application of TRIZ[6]. The cluster showcases the significant potential of innovative technologies in solving real-world problems, especially through green innovation, which can achieve a win-win situation for economic growth and environmental protection, providing new theoretical and practical support for global sustainable development [86, 87].

These clusters collectively offer a comprehensive view of the current research landscape in the field of innovation consciousness, identifying key areas of focus and revealing potential directions for future exploration.

6 TRIZ is the Russian acronym for the "Theory of Inventive Problem Solving," an international system of creativity developed in the U.S.S.R. between 1946 and 1985, by engineer and scientist Genrich S.

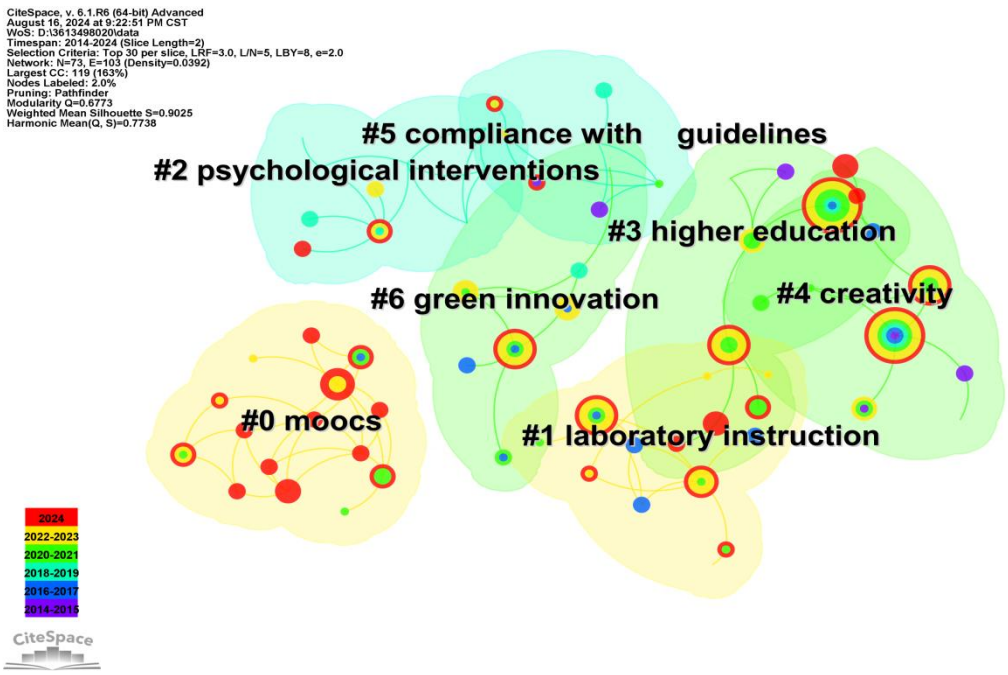

Figure 8.
Keyword clustering visualization.

As depicted in Figure 9, we incorporated a temporal dimension to analyze the development of research themes in the field of innovation consciousness, generating a timeline map. The key value of the timeline map lies in its ability to reveal the dynamic development of various research themes and the connections between them [54].

From the timeline map, we observe that different research themes within the clusters exhibit varying levels of intensity and attention during different periods. For instance, MOOCs (#0), as a relatively new research hotspot, began to receive widespread attention starting in 2022, quickly becoming a focal point of academic discussion. This trend is closely linked to the digital transformation of education, particularly in the post-pandemic era, where research on MOOCs has gradually dominated the discourse. Notably, clusters such as #3 (Higher Education), #4 (Creativity), and #5 (Compliance with Guidelines) have maintained high research intensity since 2014 and have been consistently under extensive scrutiny throughout the study period. Higher education has not only served as an incubator for innovation theory but also as a vital testing ground for innovative practices. In recent years, with the global emphasis on innovation education, research in the field of higher education has increasingly incorporated interdisciplinary content, including engineering, management, and educational technology, reflecting the indispensable role of education in social innovation and technological progress [88]. The sustained development of creativity research, particularly its intersection with education, management, and social innovation, underscores the importance of creativity as a core driver of innovation across different contexts. As the global demand for social responsibility and sustainable development continues to grow, research on compliance has increasingly intersected with themes like #6 Green Innovation, further deepening the complexity and breadth of this research area.

Additionally, the timeline map highlights the strengthening connections between key research themes. For example, there is a strong link between Psychological Interventions (#2) and Creativity (#4). Creativity, as a complex cognitive and psychological phenomenon, relies heavily on the support of psychology. Research on psychological interventions provides both theoretical foundations and practical guidance for understanding and enhancing creativity. Psychological interventions, such as behavioral decision science and cognitive training, can significantly boost individual creativity by strategically adjusting and improving psychological states, enabling researchers to help individuals overcome psychological barriers and unlock their innovative potential [89]. These interventions are applicable not only at the individual level but can also be extended to groups, such as enhancing students' innovation capacity through psychological courses or counseling within educational systems [90, 91].

Another notable connection is the intersection between Green Innovation (#6) and Laboratory Instruction (#1). With the increasing global emphasis on sustainable development goals, the relationship between laboratory instruction—a hands-on educational model—and green innovation reflects a trend of interdisciplinary integration. Green innovation requires students to master knowledge across multiple disciplines, including environmental science, engineering, and materials science. Laboratory instruction provides a practical platform for students to integrate and apply this multidisciplinary knowledge, driving the development and implementation of green technologies.

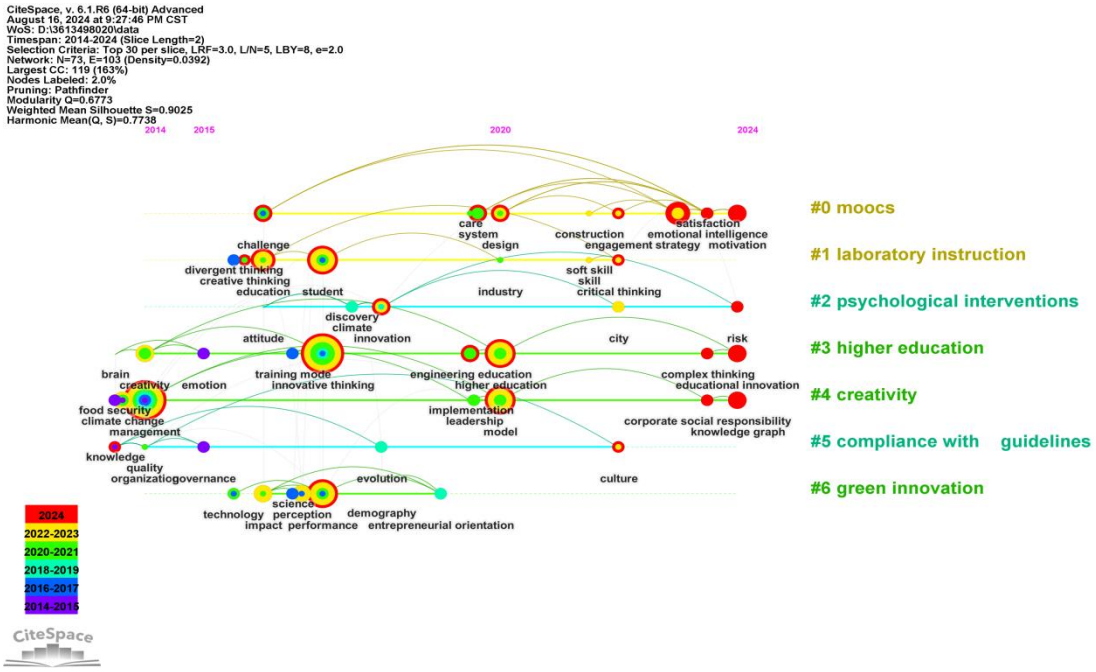

Figure 9.
Keyword clustering timeline.

Through the development and interaction of various research themes over time, the timeline map also reveals potential future research directions. With the rise of MOOCs, research on digital education platforms may further expand into interdisciplinary fields, integrating new technologies such as artificial intelligence and big data to drive further innovation in educational models. Additionally, as compliance and green innovation continue to evolve, future research may increasingly focus on how to achieve sustainable innovation goals within complex legal and policy frameworks. To further substantiate these possibilities, we conducted burst detection of keywords, as shown in Figure 10.

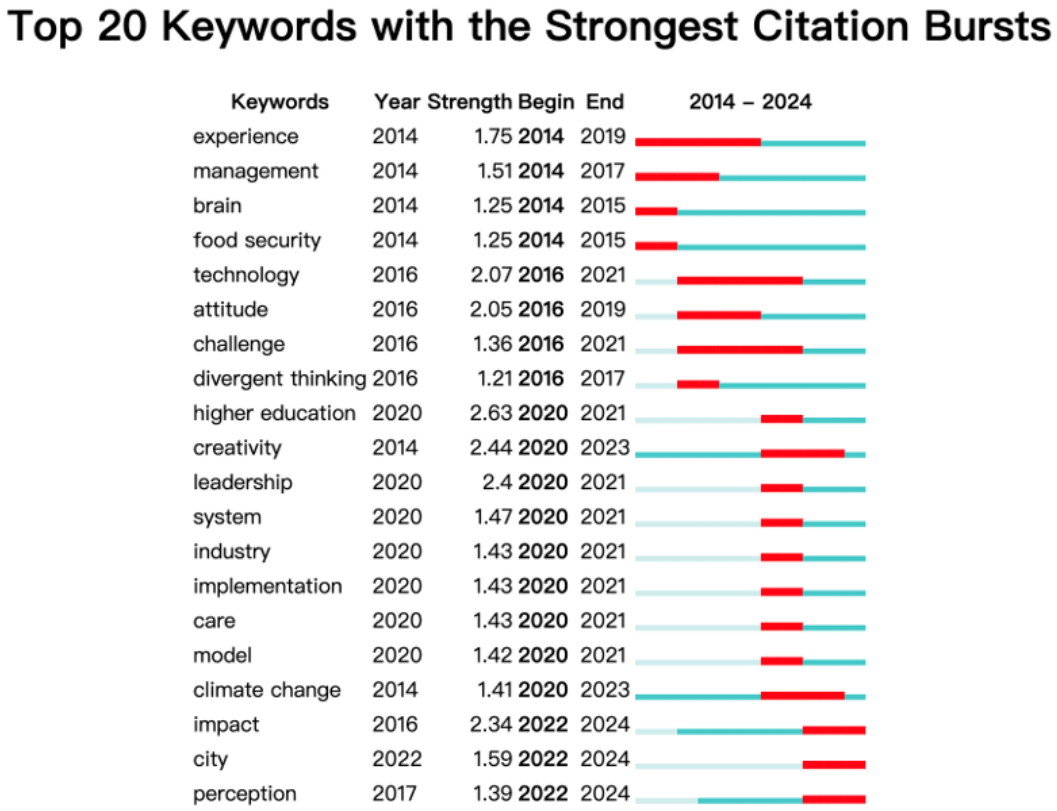

Figure 10.
Top 20 Keywords with the Strongest Citation Bursts.

In the burst analysis, we first focus on the top five keywords with the highest burst intensity. These keywords include "Higher Education" (burst intensity 2.63, 2020-2021), "Impact" (2.34, 2022-2024), "Creativity" (2.44, 2014-2023), "Leadership" (2.4, 2020-2021), and "Technology" (2.07, 2016-2021). The intensity of these bursts indicates that these terms had a particularly significant influence on innovation research during their respective time periods. "Higher Education" had the highest burst intensity from 2020 to 2021, suggesting that research on how higher education promotes innovation consciousness received widespread attention during this period. Similarly, the bursts of "Impact" and "Creativity" reflect researchers' focus on the social, economic, and environmental impacts of innovation, as well as the central role of creativity in driving the innovation process.

Next, we analyzed the five keywords with the longest duration of bursts, including "Creativity" (2014-2023), "Experience" (2014-2019), "Management" (2014-2017), "Technology" (2016-2021), and "Challenge" (2016-2021). The prolonged burst of these keywords highlights their enduring significance in innovation research. For example, "Creativity" maintained high attention for nine years starting in 2014, underscoring its central importance in innovation studies. Similarly, the sustained bursts of "Technology" and "Challenge" over six years indicate the crucial role technology plays in driving innovation and the emphasis on strategies to address challenges in the innovation process.

Furthermore, we also focused on keywords that continued to emerge until 2024, including "Impact" (2022-2024), "City" (2022-2024), and "Perception" (2022-2024). The ongoing emergence of these keywords suggests their potential importance in future research. "Impact" indicates that future studies will further explore the comprehensive effects of innovation on society, the economy, and the environment. "City" likely pertains to the development of smart cities and their role in fostering innovation. "Perception" suggests that research on user experience and market response will remain a focal area.

Based on these analyses, we can predict that future research trends will concentrate on several key areas. First, the deep integration of digitalization and higher education will continue to evolve, particularly as technology drives educational innovation, with higher education playing an increasingly vital role in cultivating innovative talent. Second, research on social impact and sustainable development will become more prominent, especially in terms of how innovative activities can achieve sustainable development goals across social, economic, and environmental dimensions. Finally, the development of smart cities and social innovation will emerge as major research hotspots, with a focus on how policies and management strategies can drive urban innovation. These research directions not only reflect current global societal needs but will also guide the future trajectory of the innovation consciousness field.

5. Conclusion and Recommendations

5.1. Main Findings

Between 2014 and 2024, research related to "innovation consciousness" globally has demonstrated significant development trends and interdisciplinary connections. The analysis of keyword co-occurrence, timelines, and time-zone maps reveals that education, management, technology, and creativity are core areas in the study of "innovation consciousness." These fields not only form the main nodes of interdisciplinary connections but also reflect a widespread global interest in how education systems can cultivate innovation capabilities, how management practices can promote innovation, and the relationship between technology application and creativity. Notably, higher education has played a critical role in fostering innovation consciousness, emerging as a key direction for future research.

Regarding the differences and commonalities between research in developed and developing countries, studies in developed countries tend to focus on innovation practices driven by technology and supported by policy, emphasizing the importance of social responsibility and sustainable development. In contrast, developing countries focus more on how improvements in education systems and the introduction of technology can enhance innovation consciousness and drive economic development. The commonality between both is the recognition of the critical role of innovation consciousness in economic and social development, pursued through dual paths of policy and education. However, the resource and technological advantages of developed countries place them at the forefront in terms of research depth and breadth, while developing countries require more policy support and international cooperation to bridge the gap.

5.2. Implications

For Policymakers: This study underscores the importance of supporting innovation consciousness through policy frameworks that integrate technological and social responsibility. Policymakers should invest in education systems and technologies that foster innovative thinking, especially in developing countries.

For Educational Institutions: Educational institutions should prioritize innovation-conscious curricula, with an emphasis on integrating digital platforms and fostering interdisciplinary approaches to innovation.

For Businesses: Organizations should recognize the role of innovation consciousness in driving technological innovation and business growth. Companies must align their strategies with evolving trends in sustainable and social innovation.

For researchers: Future studies should explore deeper into the causal mechanisms and practical implications of innovation consciousness. The study encourages the use of empirical methods to complement bibliometric findings.

5.3. Limitations

1. Timeframe and Database Limitation: This study analyzes publications only from the Web of Science between 2014 and 2024. Expanding the dataset to include other databases and extending the timeframe could provide a broader and more comprehensive understanding of innovation consciousness.

2. Bibliometric Focus: The study predominantly relies on bibliometric methods and does not deeply explore the actual implementation of innovation practices. While it provides a solid theoretical foundation, more empirical research on the real-

world application and outcomes of innovation consciousness is needed.

5.4. Recommendations for Future Research

1. Expanding Data Scope: Future research could include literature from additional databases, such as Scopus or Google Scholar, and extend the analysis to cover a broader time range to capture more evolving trends.

2. Empirical Studies: Future studies should focus on empirical research to analyze the practical application of innovation consciousness in various socio-economic contexts. Quantitative methods could assess the real-world outcomes of innovation consciousness in different countries and industries.

3. Interdisciplinary Research: Given the complex nature of innovation consciousness, further interdisciplinary studies integrating insights from management, education, technology, and sociology are necessary to develop a holistic understanding of how innovation consciousness can be fostered globally.

4. Emerging Trends in Digital Education and Sustainability: As highlighted by keyword burst analysis, future research could explore the role of digital education platforms and sustainable innovation practices, particularly in relation to smart cities and social innovation.

5.5. Final Thoughts

This study highlights the growing importance of innovation consciousness in driving global socio-economic development. By integrating technological innovation with social responsibility, stakeholders can promote the widespread application of innovation consciousness, thus fostering sustainable development across various regions. Continued research and collaborative efforts are essential for advancing this critical area of study.

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