CHAPTER

2

The contribution of nanoscience to basic research

Key findings

Physical sciences
In the subject area of physical sciences, nano-publications accounted for the largest percentage among all scholarly outputs between 2000 and 2019. Of all publications, over 12% of those in the subjects of materials science, chemistry, physics and astronomy, and chemical engineering were related to nanoscience. Materials science was the subject with the most nano-publications.

Life sciences
Nano-publications had the fastest growth in the subject area of life sciences, although the volume was small. Between 2000 and 2019, the annual growth rate of nano-publications was 5.1 times the average in the subjects of immunology and microbiology; 4.4 times the average in biochemistry, genetics, and molecular biology; and four times the average in pharmacology, toxicology, and pharmaceutics.

Engineering, energy, and pharmacology, toxicology, &

Subject differences between China and the United States
In 2000–19, China

Big Data Analysis of Nanoscience Bibliometrics, Patent, and Funding Data (2000–2019)
https://doi.org/10.1016/B978-0-323-91311-9.00002-5

pharmaceutics

Nanoscience significantly boosted the academic research impact of multiple subject areas, especially in engineering, energy, and pharmacology, toxicology, & pharmaceutics. The field-weighted citation impact of nano-publications between 2000 and 2019 in engineering was 1.9 times the average in the subject of engineering; it was 1.8 times the average in pharmacology, toxicology, and pharmaceutics, and 1.75 times the average in energy.

had a larger nano-publication share than the United States and the world in the subjects of physics and astronomy, chemistry, chemical engineering, and pharmacology, toxicology, and pharmaceutics. The United States had a larger nano-publication share than China and the world in energy, engineering, and materials science.

89%

In 2015–19, 89% of the world's most prominent research topics had at least one nano-publication in the topic's publication set.

39%

In 2015–19, 39% of the world's most prominent topics were strongly related to nanoscience, with a share of 10% or more publications in nano-research.

Top output prominent topics for nanoscience

In 2015–19, nanoscience recorded the highest academic research

Fast growing prominent topics for nanoscience

In 2015–19, nano-publications showed rapid growth in the most prominent topic output in the most prominent topic clusters,[1] including solar cells, graphene, lithium battery, plasma metamaterials, biosensor, catalysts, and semiconductor quantum dots.

clusters,[2] including DNA sequencing and tumor treatment, wastewater treatment, cellulose, organic metal, activated carbon, water purification/desalination, and quantum computing.

In this chapter, nanoscience's universality in basic science is illustrated by knowledge flow diagrams, and nanoscience's contribution to each field is evaluated by academic research output and impact. The chapter provides an analysis of nanoscience's implications for basic science research in each key country. The scientific disciplines in this chapter are categorized according to the Scopus All Science Journal Classification (ASJC) codes, in which scientific activity is classified into four subject areas, 27 subjects, and 334 fields. See Appendix D for a breakdown of the classification. The analysis is focused on eight key subjects with the highest share of nano-publications in the subject, and one subject (immunology and microbiology) as a highly relevant subject for nanoscience.

2.1 Universality: nanoscience in basic science

Knowledge flow diagram of nanoscience

Based on the subject distribution of referenced and cited publications between 2015 and 2019, a knowledge flow diagram[3] of nanoscience is

[1] The topic cluster's prominence score was in the top 5% globally and had the most nano-publications.
[2] The topic cluster's prominence score was in the top 5% globally and had the highest CAGR of nano-publications. To exclude topics with a small volume but extremely high growth rate, here we counted only topics with at least 2000 nano-publications in 2015–19. To identify emerging areas, the top 10 output topics for nanoscience were excluded, which were already mature areas in nanoscience.
[3] Some ASJC subjects were merged in the diagram; more details are listed in the Appendix.

presented (Fig. 2.1). The diagram provides a macroscopic illustration of nanoscience's impact on the basic scientific subjects. In general, nanoscience was widely distributed in the subject area of physical sciences and gradually penetrated into the subject areas of life sciences and health sciences, indicating nanoscience's emergence into multiple fields as a universal science.

The sources of knowledge of most nano-publications, as shown by their references, were the subjects of chemical engineering and chemistry; materials science; physics and astronomy; engineering; biochemistry, genetics, and molecular biology; and energy. The disciplinary distribution of the references was similar to that of the nano-publications themselves. In addition, with the development of nanoscience in life sciences and health sciences, the scope of nano-publication references also extended into various subjects of health sciences; environmental science; and pharmacology, toxicology, and pharmaceutics, as well as other fundamental sciences.

Knowledge in nano-publications flowed out to the subjects of chemical engineering and chemistry; materials science; engineering;

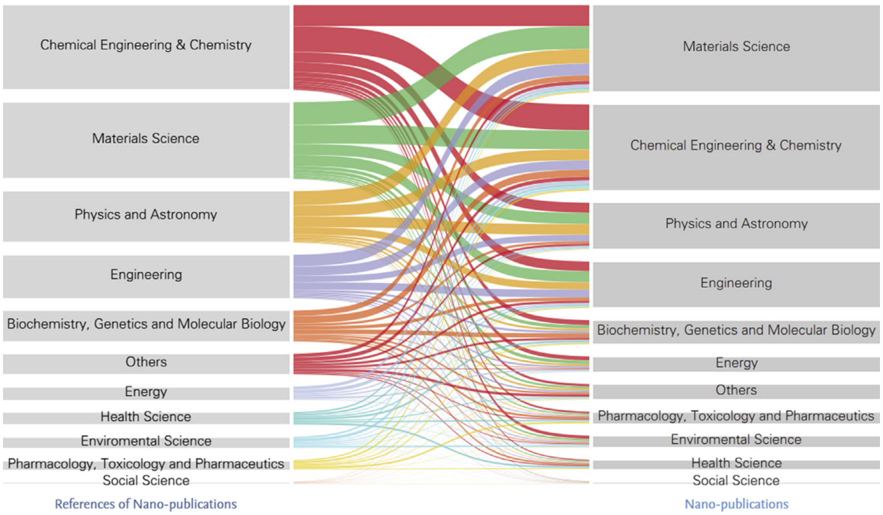

FIGURE 2.1

Knowledge flow-in diagram of nano-publications between All Science Journal Classification subjects (2015–19).

Source: Scopus.

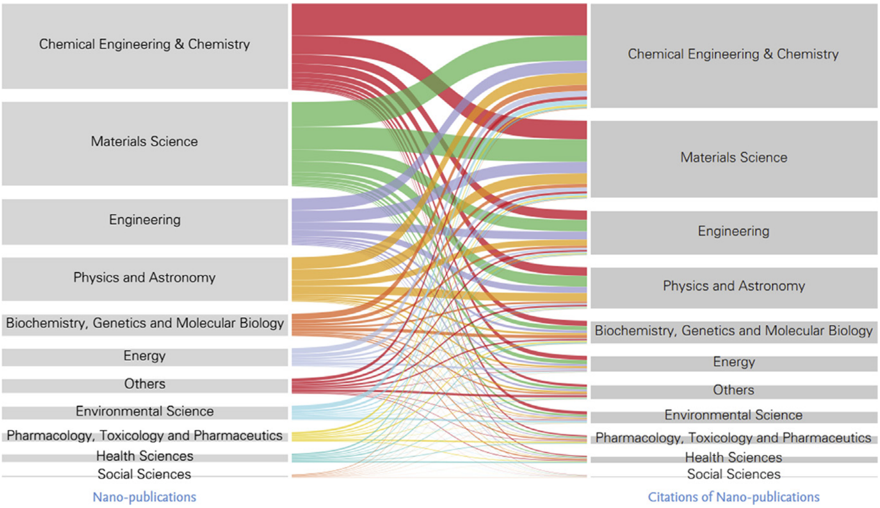

FIGURE 2.2

Knowledge flow-out diagram of nano-publications between All Science Journal Classification subjects (2015—19).

Source: Scopus.

physics and astronomy; biochemistry, genetics, and molecular biology; and energy (Fig. 2.2). Nano-publications were also cited by publications in the subjects of environmental science; pharmacology, toxicology, and pharmaceutics; and subjects in health sciences, such as medicine and dentistry, although in smaller proportions.

Nanoscience's contribution to scholarly output of basic science

The volume, share, and compound annual growth rate (CAGR) of nano-publications illustrate the impact of nanoscience on various disciplines. Nanoscience was widely applied in the subject area of physical science between 2000 and 2019 (Fig. 2.3). Within this subject area, the subjects of materials science, chemistry, physics and astronomy, engineering, and chemical engineering had the most nano-publications. Focusing on the share of nano-publications can minimize differences in scale among varying fields. However, in physical science, nano-publications still made up a high percentage of literature. Nano-publications were attributed to 20.7%, 17.7%, and 16.3% of

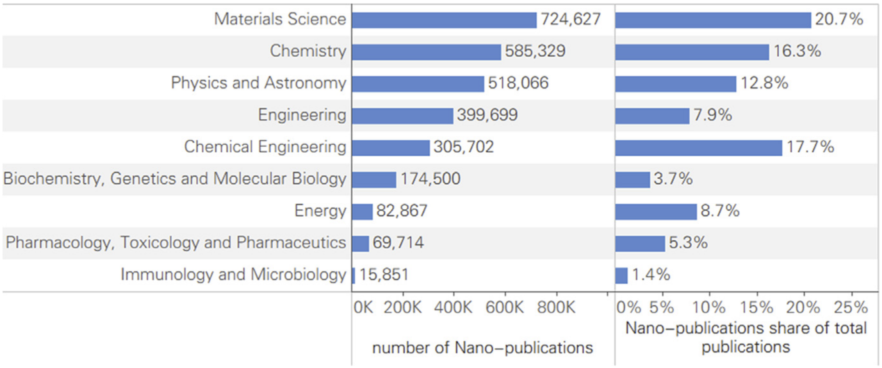

FIGURE 2.3

Nano-publications' share of scholarly output in key subjects (2000–19).

Source: Scopus.

total articles in materials science, chemical engineering, and chemistry, respectively.

The CAGR of nano-publications was higher than average in each comparator subject (Fig. 2.4, with a relative CAGR of >1[4]) in 2000–19. Among them, the growth rate of nano-publications in immunology and microbiology was 5.1 times the subject's average.

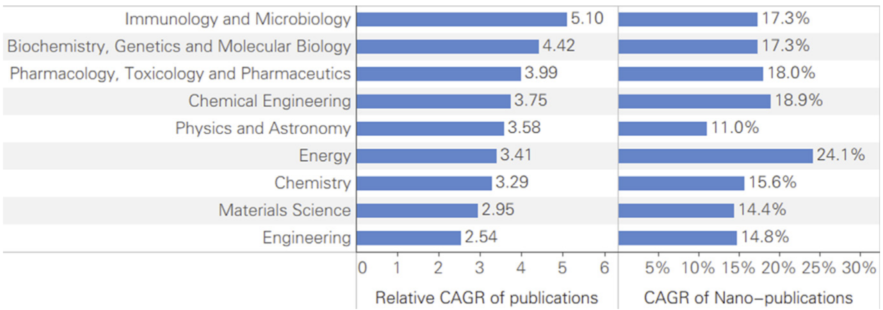

FIGURE 2.4

Relative compound annual growth rate (CAGR) and CAGR of nano-publications in key subjects (2000–19).

Source: Scopus.

[4] Relative CAGR = CAGR of nano-publications in the subject/CAGR of all publications in the subject.

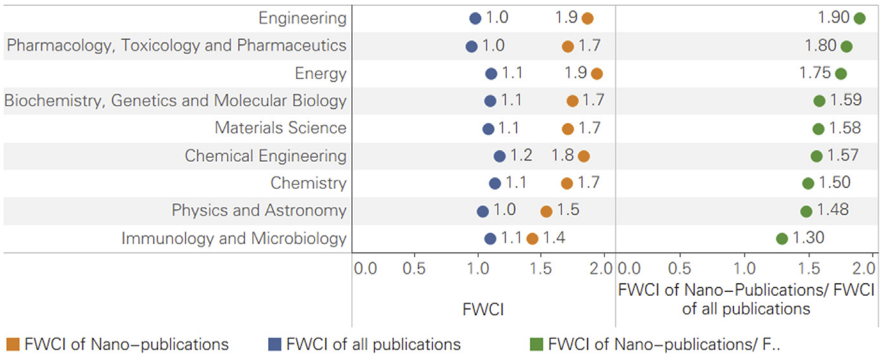

FIGURE 2.5

Comparison of nano-publications' field-weighted citation impact (FWCI) and average FWCI in key subjects (2000–19).

Source: Scopus.

Nanoscience's contribution to academic impact of basic science

The field-weighted citation impact (FWCI) of nano-publications was higher than the FWCI for all publications in each analyzed subject (Fig. 2.5). Among them, the FWCI of engineering increased the most. Between 2000 and 2019, the FWCI for nano-publications in engineering was 1.9 times the average, followed by 1.8 times the average in pharmacology, toxicology, and pharmaceutics, and 1.75 times in energy.

Nanoscience's contribution to basic science in key countries

Scholarly output

Nano-publication shares in materials science, chemical engineering, and chemistry were the highest in the world between 2000 and 2019 (Fig. 2.6). The United States had a higher nano-publication share than China and the world in energy, engineering, and materials science. China held a higher percentage of nano-publications than the United States and the rest of the world in physics and astronomy, chemistry, chemical engineering, and pharmacology, toxicology, and pharmaceutics. Immunology and microbiology had the smallest share of publications in nanoscience of the subjects, but its relative growth rate was

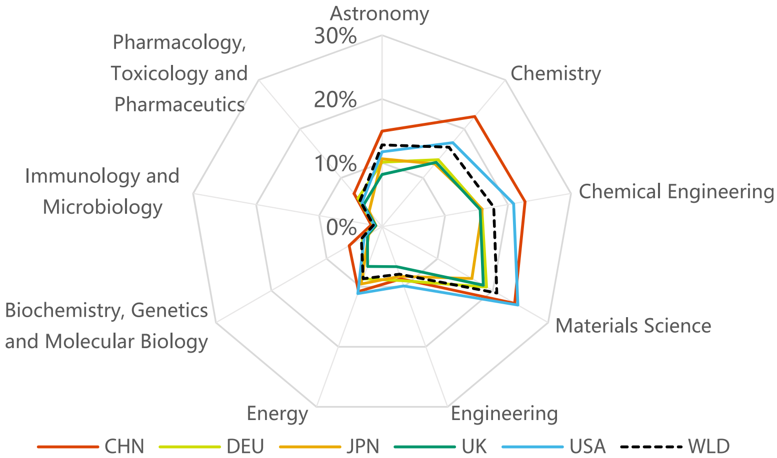

FIGURE 2.6

Nano-publications' share in key subjects in each comparator country and the world (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

higher than those of the other subjects (Fig. 2.4), indicating the trend of disciplinary integration between nanoscience and this subject.

Fig. 2.7 illustrates the share of nano-publications in key subjects, for each key country and the world. It shows that the percentage of nano-publications was growing in all nine subjects between 2000 and 2019 for all key countries and the world. However, the growth rates of these publications varied slightly across subjects and countries.

Academic impact

The FWCI of nano-publications in each subject listed subsequently was higher than the respective subject's overall average FWCI, indicating that nanoscience has enhanced the academic impact in multiple subjects in each key country (Fig. 2.8).

Especially in China, nanoscience boosted the academic impact of various subjects. Between 2000 and 2019, in most of the subjects subsequently, the FWCI of China was lower than those of the United States, the European countries, and the world average. However, as nanoscience became integrated into these subjects, China's academic impact started to rise. The increase in FWCI was especially significant in the energy and biochemistry, genetics, and molecular biology subjects.

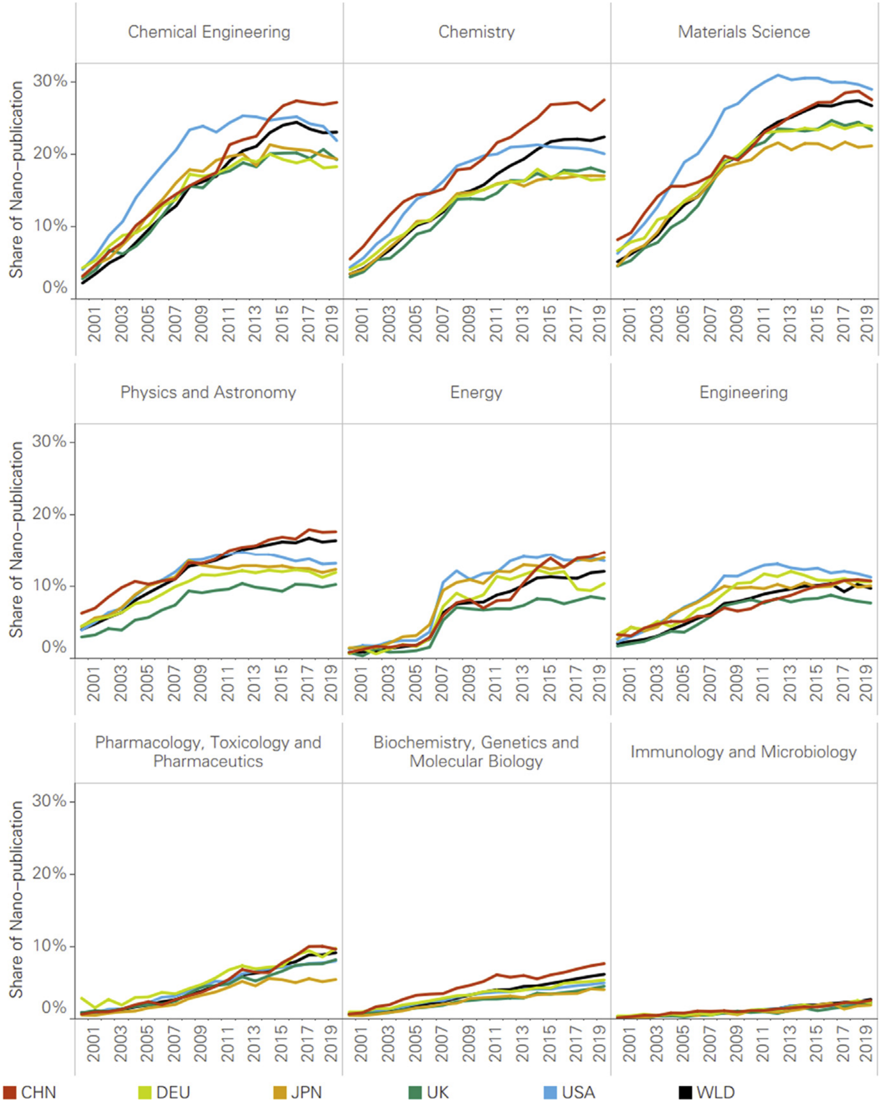

FIGURE 2.7

Trends of nano-publications' share in key subjects, for each comparator country and the world (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

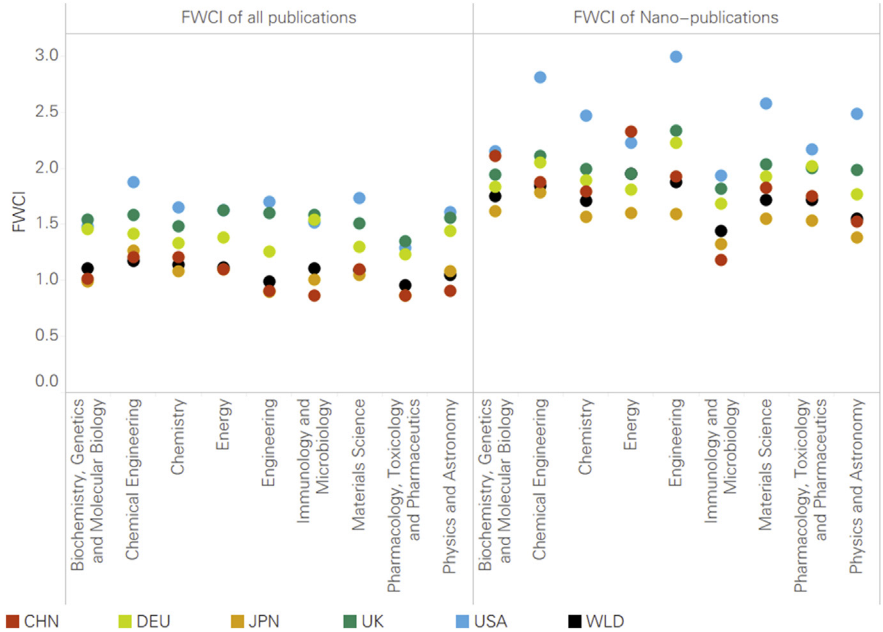

FIGURE 2.8

Field-weighted citation impact (FWCI) of overall publications and nano-publications in key subjects in each country (2000–19). *CHN*, China; *DEU*, Germany; *JPN*, Japan; *UK*, United Kingdom; *USA*, United States; *WLD*, world.

Source: Scopus.

2.2 Advanced science: nanoscience in highly prominent topics

The term "topics" refers to nearly 96,000 research topics created using the citation patterns of Scopus-indexed publications. A topic is a dynamic collection of documents with a common focused intellectual interest. The methodology for using citation patterns to define research topics was developed through an Elsevier collaboration with research partners. A topic is created in which linkages within the topic are strong and linkages outside the topic are weak.[5] This methodology

[5] Learn about topics and topic clusters: Topic Prominence in Science FAQs - SciVal Support Center.

considers 95% of articles available in Scopus from 1996 to the present and clusters them into nearly 96,000 unique, global research topics based on citation patterns.

The Prominence score is an indication of the momentum related to a particular topic. Prominence is a linear combination of citations, views, and journal impact for a given topic, in which each factor is normalized by the topic's standard deviation. More details can be found in Appendix B. The Prominence score has been shown to correlate with topic-level funding per author in a US sample of funded grants. The analysis found that on average, the higher the Prominence score, the more money per US author was available for research on that topic.[6]

Topic clusters are a higher-level aggregation of these research topics based on the same direct citation algorithm that creates the topics. Although topics are easy to understand for their respective subject experts, they are more difficult for subject generalists. To aid discovery and understanding of the topics, we have taken the topics and aggregated them into around 1500 topic clusters. When the strength of the citation links between topics reaches a threshold, a topic cluster is formed.

In this section, we will analyze the performance of nanoscience in the world's most prominent topics.

Nanoscience's connection with the most prominent topics

The world's top 1% most prominent topics represent research areas with the most attention and popularity. In total, there are around 960 topics with the Prominence score ranked in the top 1% worldwide.

Based on the percentage of nano-publications in highly prominent topics, nanoscience's contribution and correlation to these topics were evaluated in this study. The number of topics and their different proportions of nano-publications are aggregated in Table 2.1:

[6] Richard Klavans, Kevin W. Boyack, Research portfolio analysis and topic prominence, Journal of Informetrics, Volume 11, Issue 4,2017, pages 1158–1174, ISSN 1751–1577, https://doi.org/10.1016/j.joi.2017.10.002.

Table 2.1 Distribution of nano-publications shares in top 1% high-prominence topics (2015–19).

Proportion of nano-publications in most prominent topics	Number of world's top 1% high-prominence topics	Share of all top 1% high-prominence topics (2015–19)
Nano-publications share in topic: ≥90%	26	3%
Nano-publications share in topic: 70–90%	68	7%
Nano-publications share in topic: 50–70%	63	7%
Nano-publications share in topic: 30–50%	67	7%
Nano-publications share in topic: 10–30%	151	16%
Nano-publications share in topic: 5–10%	68	7%
Nano-publications share in topic: 1–5%	188	20%
Nano-publications share in topic: <1% (>0%)	226	24%
No nano-publications in topic	102	11%

From Scopus, SciVal.

- Among the world's most prominent topics globally, 89% were related to nanoscience, meaning they had at least one nano-publication. These topics were widely distributed across multiple subject areas (Fig. 2.9).
- Up to 40% of the world's most prominent topics strongly correlated to nanoscience, meaning the share of nano-publications in these topics was 10% or more. Among them, 26 topics had a nano-publication percentage of over 90%.

By analyzing the correlation between nanoscience and each subject area's hottest topics, which are prominent topics that rank in the top 1% globally, we can better understand nanoscience's impact on these topics.

Based on our analysis, in 18 of the 27 ASJC subjects,[7] over 70% of the most prominent topics had at least one nano-publication. Furthermore, 16 of the ASJC subjects strongly related to nanoscience, meaning that the topics had 10% or more nano-publications. As shown in Fig. 2.10, nanoscience was strongly correlated to the most

[7] Scopus has 27 ASJC subject areas.

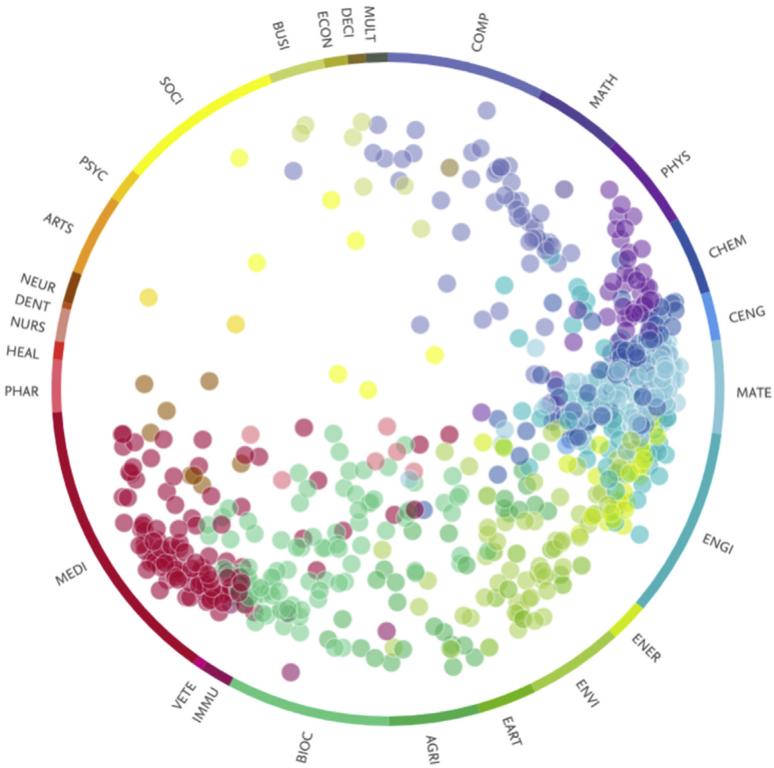

FIGURE 2.9

Subject distribution of the world's top 1% high prominence topics with nano-publications (2015–19). Each *dot* represents a topic; a *dot's color* represents the subject area to which the dot belongs.

Source: Scopus, SciVal.

prominent topics[8] in materials science (85.4% of the most prominent topics in materials science have at least 10% of publications related to nanoscience), physics and astronomy (78.9%, respectively), chemistry (76.7%, respectively), chemical engineering (73.2%, respectively), engineering (64.2%, respectively), energy (50.0%, respectively), and pharmacology, toxicology, and pharmaceutics (42.9%, respectively).

[8] Topic prominence score ranking in the top 1% worldwide.

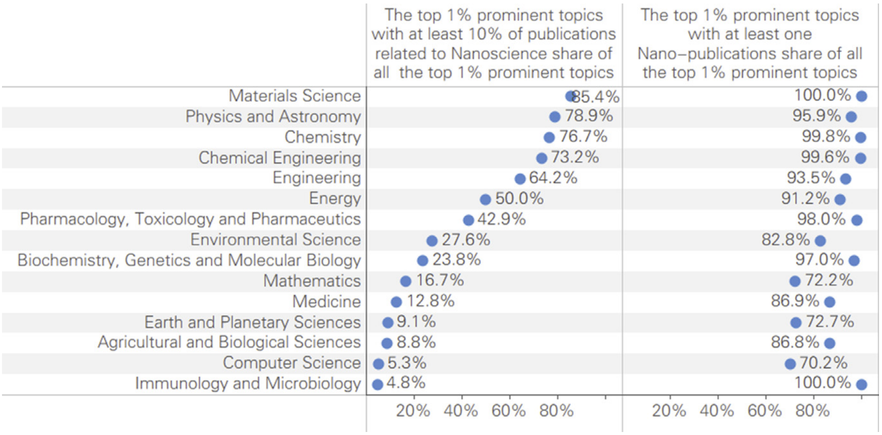

FIGURE 2.10

Correlation analysis of nanoscience and high-prominence topics in each subject area in the world (2015—19).

Source: Scopus.

The most prominent topic clusters related to nanoscience

Topic clusters are aggregations of topics with similar interests that form a broader, higher-level area of research. These topic clusters can provide a deeper insight into ongoing research done by countries, institutions, and scientists, before drilling down into the underlying niche topics. In this section, we analyzed prominent nano-related topic clusters, which were those ranked in the top 5% in the world, based on the scale and growth of their scholarly output.

The highly prominent topic clusters with the most nano-publications (2015–19)

Between 2015 and 2019, the top 5% of worldwide topic clusters by prominence[9] with the most nano-publications were solar cells, graphene, lithium batteries, plasmonic metamaterial, biosensors, catalysts,

[9] Topic clusters with prominence scores ranking in the top 5% globally.

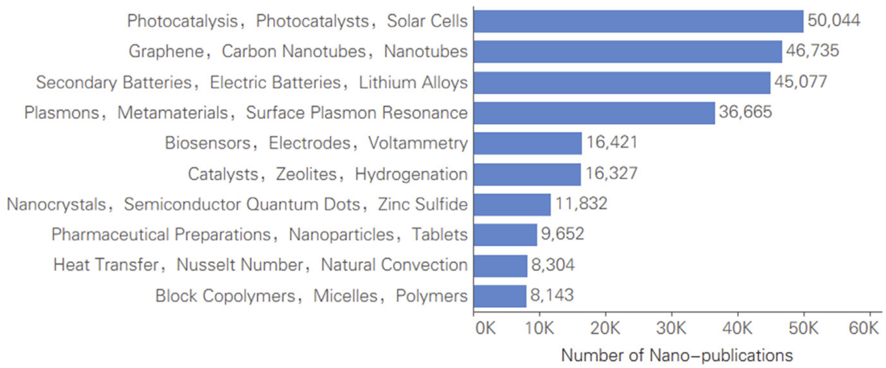

FIGURE 2.11

Top 10 topic clusters with a prominence score in the top 5%, by nano-publications in topic clusters (2015—19).

Source: Scopus, SciVal.

semiconductor quantum dots, pharmaceutical nanoparticles, and polymers (Fig. 2.11).

In the topic cluster "Photocatalysis, Photocatalysts, Solar Cells," the term "nano" chiefly relates to nanorods, perovskite, and solar cells. The five publications with the highest citations in this topic cluster were all related to perovskite solar cells.

Nanoscience application in the "Biosensors, Electrodes, Voltammetry" topic cluster was mainly reflected in the combination of biosensor, electrochemistry and graphene, nanoparticles, glassy carbon, and similar topics. Studies representing the cluster included electrochemical sensors and biosensors based on nanomaterials and nanostructures, electrochemistry of graphene-related materials, and so forth.

Applications of nanoscience in the "Pharmaceutical, Preparations, Nanoparticles, Tablets" topic cluster were mainly related to nanotechnology in the pharmaceutical industry. Research that represented the cluster included nanoparticles applications and the nanostructured lipid carrier in drug delivery systems.

The Highly prominent topic clusters with the highest growth rate, by nano-publication output (2015–19)

The 10 highly prominent topic clusters[10] (Fig. 2.12) with the fastest-growing nano-publication output demonstrated the dynamic application of nanoscience in DNA sequencing and tumor treatment, wastewater treatment, cellulose, metal-organic framework, activated carbon, water purification/desalination, quantum computing, and so forth. The exponential growth in publication count has reflected the integration and rapid development of nanoscience in emerging research areas.

Among the top 10 topic clusters, "MicroRNAs, Long Untranslated RNA, Neoplasms" had the fastest-growing nano-publication output. Studies that represent the cluster include applying nanotechnologies in the fields of DNA sequencing, peptide detection, microRNA detection, and delivery carriers for targeted therapeutic drugs.

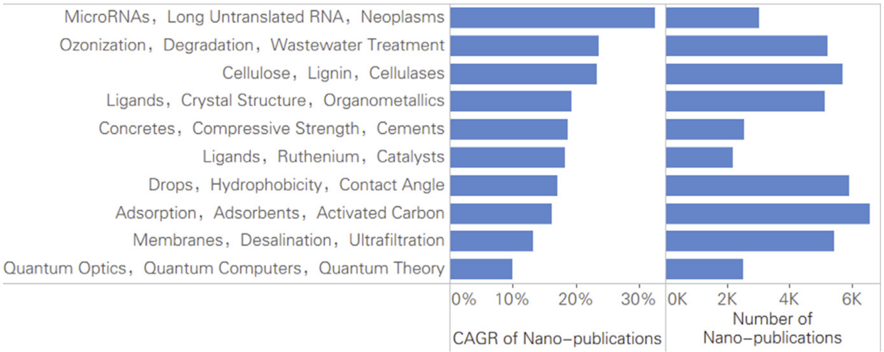

FIGURE 2.12

Top 10 topic clusters with a prominence score in the top 5%, by compound annual growth rate (CAGR) of nano-publications in the topic clusters (2015–19).

Source: Scopus, SciVal.

[10] The topic cluster's prominence score was in the top 5% globally and had the highest CAGR of nano-publications. To exclude topics with a small volume but extremely high growth rate, here we counted only topics with at least 2000 nano-publications in 2015–19. To identify emerging areas, the top 10 output topics for nanoscience were excluded, which were already mature areas in nanoscience.

In addition, there were three topic clusters related to water treatment: ozonization, degradation, and wastewater treatment. They included studies such as "Environmental Remediation and Application of Nanoscale Zero-Valent Iron," and "Drops, Hydrophobicity, Contact Angle." There were representative research in nanomaterials and nanostructure, such as the hydrophilicity and hydrophobicity of nanobubbles and nanodroplets; and membranes, desalination, and ultrafiltration. Studies investigating the applications of nanofiltration, nanofilms, and nanofiltration membranes in water desalination and purification were also included. These hot research areas reflect the increasing development of nanoscience in environmental management, especially in water treatment.