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Bibliometric Analysis of the Development of International Scientific Collaboration of Nguyen Tat Thanh University (Vietnam) over the last Decade

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Abstract

This study explores the key features of scientific articles resulting from international collaborations between Nguyen Tat Thanh University (NTTU), a private higher educational body in Vietnam, and scholars from other countries during the 2011-2023 period. Metadata of 1505 articles indexed in the Scopus database has been downloaded to conduct a bibliometric analysis using VOSviewer and Biblioshiny software. Findings reveal that NTTU's international collaboration publication record can be divided into two main sub-periods: before 2018, accounting for only 9% of the total publication, and after 2019, comprising over 91%. The major contributors to NTTU's international collaboration come from scholars in Korea, the USA, and Singapore, while contributions from scholars in other countries are relatively less significant. Only three strong research groups are identified, led by some permanent scientists of NTTU, and some from other institutions in Vietnam, Singapore and the USA. Consequently, the diversity of strong research directions of NTTU is somewhat restricted, primarily focusing on a few specific topics with medical science, wastewater treatment, adsorption, and photocatalysis. Excluding most cited articles in the field of medical science, main authors of nine over ten the top cited articles in other research fields are not permanent scientists of NTTU, suggesting that contributions of NTTU in these important studies were not significant.

Keywords: *International Collaboration, Nguyen Tat Thanh University, Bibliometric Analysis*

INTRODUCTION

International Collaboration Among Universities

International cooperation is the peaceful coordination among international entities to achieve common goals or the collaboration among nations to meet the needs of their people (W. W. Y. Chan, 2004). International cooperation in higher education is increasingly important in today's globalized world. The trend towards internationalization facilitates the expansion and diversification of collaborative agreements in higher education, promoting vigorous implementation. This includes the establishment of university consortia, which play a vital role in facilitating cooperation and knowledge exchange among institutions. The significance of international cooperation in higher education is further underscored by the needs to ensure quality education across borders (E. Beerkens and M. Derwende, 2007). Countries like China, the United States, the United Kingdom, and Singapore are actively establishing world-class institutions and engaging in collaboration to attract international students and foster relationships with a global network of universities. This clearly demonstrates the role of international cooperation in promoting diversity and cross-cultural understanding in higher education. Internationalization and academic collaboration are closely intertwined, exemplified by successful models such as the Europa Chair (C. H. J. DePeña and M. J. Arrieta, 2012). International cooperation in higher education not only facilitates knowledge exchange among nations and provides a foundation for quality education but also promotes diversity and cross-cultural understanding. International collaboration plays a significant role in shaping the future of higher education in the context of globalization (Henk Kummeling, 2022).

Entering the era of globalization amidst the Fourth Industrial Revolution has transformed traditional higher education into digital higher education. Aspiring to become world-renowned institutions is a goal pursued by every university. Universities maintain international partnerships to achieve this objective and share benefits

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among themselves. One of the most crucial reasons for international cooperation is competition and survival in the market-oriented education environment (W. W. Y. Chan, 2004). Internationalization of education is one of the crucial requirements that help higher education institutions enhance quality, reputation, and global rankings. Alongside the broad scope of internationalization strategies, the development of international cooperation and strategic partnerships, ranging from teaching to research, is considered vital for survival and growth (M. M. Kiselova, 2020). The research by Kiselova and colleagues has demonstrated that international cooperation between higher education institutions can take various forms, including: enhancing academic and managerial capacities of higher education institutions; improving the quality of higher education; enhancing the effectiveness of the higher education system; improving human resource quality; enhancing international reputation; expanding student and faculty exchanges in educational and research projects; enhancing learning effectiveness; and increasing intercultural awareness for students. The basic principles of cooperation between higher education institutions will be governed by cooperation agreements between the parties, typically through a memorandum of understanding signed for a maximum of 3 years or bilateral agreements (M. M. Kiselova, 2020).

International cooperation activities in the field of education are manifested in the following 7 basic contents (G. T. Anna Filatova, 2021): (1) Developing and implementing science and education programs linked with international or foreign organizations; (2) Sending lecturers, students, and research staff to foreign educational institutions with opportunities to receive special scholarships for studying abroad; (3) Accepting foreign students, teachers, and researchers into host institutions for training, professional development, and improvement of scientific and educational activities, including international academic exchanges; (4) Collaborating on scientific research, fundamental and applied research in the field of education, and implementing innovative activities; (5) Participating in online education program implementations; (6) Engaging in activities of international organizations and carrying out international education, research, scientific, and technical projects, congresses, symposiums, conferences, workshops, or conducting these events independently; and (7) Exchanging educational and scientific materials on a bilateral and multilateral basis.

Within the framework of international cooperation, higher education institutions strive to attract students from around the world, as such actions enhance the internationalization process. Universities endeavor to attract students through proposed initiatives, offering opportunities for domestic students to travel and study abroad through exchange programs, as well as providing professionally tailored training to meet the needs of potential employers. Higher education institutions can also gain competitive advantage by sponsoring partnerships between multicultural universities, as they enhance the academic and scientific development of higher education institutions, and create opportunities for exchange not only among students but also among educators within existing programs and specially designed programs (Quacquarelli Symonds (QS), 2019). International cooperation at universities is greatly influenced by investment policies of both the institutions themselves and the government. Specifically, international collaboration in higher education is impacted by factors such as financial and economic considerations, organizational and legal aspects, political factors (external influences), and personnel management (internal factors). In managing development activities, administrators need to consider these factors, develop strategies that align with local characteristics, societal needs, legal compliance, and enhance internal capabilities (Oleksandr Kovalenko; Olena Khil; Liudmyla Ovsiankina, 2021). The factors influencing international cooperation activities at universities include (A. Fortina Febriani, 2018): (1) Human resources: including personnel responsible for managing international cooperation activities; (2) Financial resources: encompassing the entire budget, infrastructure, and technology to aid in achieving goals in international cooperation; (3) Power: the legitimate power granted within the social structure allowing educational institutions to fulfill their functions; (4) Organizational structure: the organizational structure outlined in the organizational chart, detailing tasks from top-level positions to subsidiary tasks; and (5) Roles, responsibilities, system coordination, understanding of capital forms necessary to be managed in education are also influencing factors affecting the ability to implement work plans.

International Cooperation at Nguyen Tat Thanh University

Vietnamese Law of Education, issued in 2004, specifies that forms of international cooperation in education include: (1) programs, projects in collaboration with foreign countries utilizing official development assistance (ODA) funding; (2) exchange of information, experiences in the field of education; (3) international conferences, workshops, and seminars on education within and outside the country (Vietnamese Gorvernmen, 2024). The decree serves as a foundation for promoting increased international cooperation among universities. However, Tran (2009) has pointed out some limitations and weaknesses in the management of international cooperation activities by the state, such as: In reality, the training linkage process is still lacking, not fully complying with the law leading to foreign educational institutions taking advantage, affecting the interests of learners; the licensing of training linkage activities is not standardized, with overlaps between ministries and departments; spontaneous linkages between training institutions are difficult to manage in terms of programs, procedures, locations, equipment, leading to training quality that is not reliable, not commensurate with the efforts and expenses students need to bear; inspection, examination, and quality assurance activities are still immature, lacking the necessary intensity to prevent negative outcomes (Tran, 2009). As being a developing country, in order for Vietnamese universities to integrate internationally, educational institutions and universities have to enhance their professional capacity, develop educational programs, and promote international cooperation. Specifically, they have to focus on three factors: financial resources, human resources, and management mechanisms (Nguyen, 2021)

Nguyen Tat Thanh University (NTTU) is one of the private universities in Vietnam, established in 2005 with a training scale of over 30,000 students, learners, and doctoral students across 20 faculties. It offers 51 undergraduate programs, 12 master programs, 4 doctoral programs. Nguyen Tat Thanh University currently employs 1,179 full-time lecturers, including 792 with master's degrees and 320 with doctoral degrees.(Nguyen Tat Thanh University, n.d.). On April 26, 2021, NTTU issued regulations on international cooperation, outlining specific objectives to be achieved through international cooperation activities, focusing on (1) enhancing the quality of education, fostering scientific and technological development, engaging with regions and the world, and aligning with the university's conditions; (2) developing a highly qualified personnel; and (3) enhancing the university's status, gradually building the university into a prestigious international educational institution. To achieve these objectives, effective management mechanisms for financial and human resources are necessary, capable of meeting the distinct characteristics and requirements of the university (Nguyen Tat Thanh University, n.d.).

Therefore, creating and developing strategies, effective management solutions for international cooperation activities of NTTU is extremely important and necessary. International cooperation issues have been addressed by NTTU through establishing relationships with hundreds of universities, research institutes, and international organizations from over 20 countries (such as the United States, United Kingdom, France, Germany, South Korea, Poland...) and signing more than 250 MoU, cooperation agreements with partners. The university also welcomes international students from countries such as Laos, Cambodia, South Korea, the Philippines; meanwhile, it implements student and faculty exchange programs to enhance the quality of education. Through organizing conferences, international scientific conferences, NTTU has successfully held many workshops attracting scholars, scientists from renowned universities worldwide; the university also attracts the consultation of many leading professors from prestigious universities, research institutes, holding the role of honorary professors. In 2008, the International Education Institute (NIIE) was established. Over 15 years of formation and development, NIIE has cooperated and linked with many countries and advanced education systems worldwide. During the development process, NIIE has partnered with Edexcel Organization (United Kingdom); FTMS Academy (Singapore) and Chisholm Institute (Australia); NIIE has been accredited by the Accreditation Service for International Schools, Colleges, and Universities (ASIC), United Kingdom - a prestigious accreditation organization recognized by the Government of the United Kingdom, specializing in evaluating and accrediting the quality of training programs, universities, and colleges in the United Kingdom as well as many universities and colleges worldwide; In 2013, NIIE also cooperated with Coventry University (United Kingdom); NIIE has made a mark by successfully developing the International Standard Bachelor's program through forging connections and building training programs based on the curriculum of reputable universities worldwide in 2015; In 2016, NIIE became a member of the Quality International Study Abroad Network (QISAN); In 2019, the International Standard program has been recognized for credit transfer to

universities in the United Kingdom, Finland, and Singapore; In 2020, NIIE officially enrolled students in the credit transfer program to Angelo State University (United States) (Nguyen Tat Thanh University, n.d.). Currently, the Institute has more than 2,000 students enrolled in three programs accredited to international standards, producing globally competitive human resources. Additionally, the university actively organizes workshops, student and faculty exchanges, participation in international forums. Cooperation agreements have also been signed with many universities, academies, businesses, and organizations in many countries worldwide (Table 1).

Table 1: Prominent international cooperation events over the past 10 years

(Source: Author group compiled from the website of Nguyen Tat Thanh University).

Time	Prominent cooperation events
5/2017	Knowledge exchange workshop with Birmingham City University, UK
7/2017	International Conference on the 4.0 University Model – Foundation of 21st Century Education
11/2017	International Conference on Exploring Pedagogical Approaches Supporting Academic Learning in the International Context
6/2018	Attending the 14th International CDIO Conference in Kanazawa, Japan
5/2019	Participating in the Vietnam-Laos Training Quality Enhancement Forum and Vietnam Education Exhibition.
9/2019	Workshop on High-Income Employment Opportunities and Roundtable with German Partners
11/2019	Signing memorandum of understanding for cooperation with Saint Rose College, USA
10/2020	Signing a cooperation agreement with the Institute of Chartered Accountants in England and Wales (ICAEW)
3/2021	Signing a memorandum of understanding on cooperation with the Asian Institute of Technology (AIT)
9/2021	Organizing an exchange program between students of the school and high school students from Shotoku High School and Chihaya High School, Japan
11/2021	Organizing the international conference "The Energy Security and Chemical Engineering Congress, ESChE 2021
2/2022	Becoming an affiliated member of the Francophone University Agency (AUF)
5/2022	Collaboration with ASIA SAFE – ERASMUS+
4/2023	Signing of the Memorandum of Understanding for cooperation and Education Workshop with Veliko Tarnovo University (Bulgaria)
4/2023	Signing of the Memorandum of Understanding for cooperation with Josai International University (Japan)
6/2023	Organizing the International Conference "Digital Transformation – Blockchain Technology and Financial Technology 2023

Table 2: Programs and international cooperation projects over the past 10 years

(Source: Author group compiled from the website of Nguyen Tat Thanh University)

Time	Collaborative programs and projects	Organizations and countries for cooperation
2016 - 2019	Digitization and curriculum redesign focusing on student-centered teaching methods to enhance outcome standards towards career orientation in the context of Vietnam	British Council, Birmingham University, UK
2016-2019	Integrating teaching and learning: Revisiting cross-national educational partnerships to establish a collaborative community in practical application and teaching	British Council, Birmingham University, UK
2016-2019	Enhancing employability support for students through student-centered teaching methodologies	Birmingham University, UK
2020 – 2022	Surveying the labor market at Vietnamese universities	University of Padova (Italy) and University of Salamanca (Spain)
2018 – 2019	Developing an internationally innovative approach to pharmaceutical education transformation.	University of East Anglia (UK), British Council
2019 – nay	Developing an innovative and effective training partnership model for teaching natural products (Phase 2)	University of East Anglia (UK), British Council
2021-2024	Digi-Doc: Digital Doctorate Training Hub	Birmingham City University (BCU), Ho Chi Minh City University of Education (HCMUE), Vietnam National University, University of Education (VNU – UEd), Northeast Normal University, China (NENU), Universitas Negeri Yogyakarta (UNY)

Thanks to the strong development of international cooperation activities, the number of publications with NTTU affiliation published in international scientific journals has increased quickly, especially during the last decade. It is necessary to quantitatively analyze metadata of publications from NTTU which were results from international collaborations, because the outputs of these analyses can be used to evaluate the effectiveness of

NTTU's policies in fostering scientific and technological development. In addition, these policies can make NTTU becoming a model for other universities, in Vietnam and other developing countries, with similar conditions to refer to. In order to achieve this objective, bibliometric analysis has been selected because it is among the best approaches for quantitative investigation of the development of scientific activities based on the content of scientific literature (Broadus, 1987). This study combines two popular software tools for bibliometric analysis, namely Biblioshiny and VOSviewer. Biblioshiny (Bibliometrix) is a web-based graphical interface software, programmed in the R language to facilitate integration with other R packages. It was developed by Massimo Aria and Corrado Cuccurullo from the University of Naples and Luigi Vanvitelli of the University of Campania (Italy). It primarily works with data from WoS, Scopus, and Dimensions. The intuitive interface includes seven main analysis sections based on charts: (1) Overview, (2) Sources, (3) Authors, (4) Documents, (5) Conceptual Structure, (6) Intellectual Structure, and (7) Social Structure. It provides charts and analyses of publication performance by scientists and scientific management organizations. VOSviewer is a software tool designed to build and visualize bibliometric networks, with journals, researchers, or individual publications as nodes, based on co-citation, bibliographic coupling, or co-authorship relationships. It also allows the construction of networks of simultaneously occurring terms extracted from a corpus of scientific documents, using text mining functionality. It was developed by the Centre for Science and Technology Studies (CWTS) at Leiden University (Netherlands). It can extract bibliometric networks on co-authorship, co-occurrence, and citation-based data from various bibliographic databases including WoS, Scopus, Dimensions, PubMed, and RIS format. (Moral-Muñoz et al., 2020). The selection of these two software tools for analyzing metadata of international scientific collaboration database of NTTU aims to answer the following questions:

Question 1: What is the quantity and trend of publications in international collaboration by Nguyen Tat Thanh University over the past decade?

Question 2: What are the research fields involved in the international collaboration of Nguyen Tat Thanh University over the past decade?

Question 3: How is the quality of international collaborative papers by Nguyen Tat Thanh University over the past decade?

Question 4: What are the international collaboration networks, and what are the emerging trends in international collaborative publications by Nguyen Tat Thanh University over the past decade?

Scientific Bibliometrics Analysis

Bibliometrics is the process of evaluating and measuring indices, data, and information related to the bibliography or document collection of an organization or individual(Chellappandi & Vijayakumar, 2018). Bibliometric analysis is commonly used to conduct statistical research from various perspectives, including analyzing and quantifying the characteristics of publications. Bibliometrics is also used to analyze networks of related bibliographic factors in documents, including co-authoring networks, co-citation, co-occurrence of keywords, bibliographic coupling, and so on (Van Eck et al., 2010). Bibliometrics is a collection of mathematical and statistical methods used to analyze and measure the quality and quantity of books, journals, and other types of publications(Waltnam & Noyons, 2018). Bibliometrics is a research field within library and information science that studies bibliographic materials using quantitative methods.The results of bibliometric research are used to measure the relevance of a topic, the contributions of journals, and educational institutions, and countries in that research field(Farrukh et al., 2021). Bibliometrics can demonstrate information about a particular field to researchers by investigating various publishing characteristics, such as authorship, sources, organizations, journals, citations, author affiliations, and even citation networks (Huang et al., 2021).

The method of bibliometric analysis and visualization is employed to systematically study and analyze large datasets available in the Web of Science Core Collection, including the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI(Ellegaard, 2015):

Identifying the process from historical to present publications related to an issue or research field.

Analyzing the research trends of a particular issue or scientific field.

Providing evidence of the significance and impact of the research issue or field currently being studied.

Identifying the strengths and weaknesses of current research, while also identifying new and emerging research areas.

Identifying significant publications and their level of impact on the research topic.

Identifying potential collaborators/institutions for collaboration through analyzing the publication effectiveness of individuals/organizations. Identifying suitable journal outlets for publishing research findings.

Bibliometric analysis begins with selecting the most suitable data source that aligns with the scientific scope of the researcher's field of study. There are numerous bibliographic databases available, such as PubMed, EMbase, SpringerLink, among others. However, not all of them provide information readily accessible for bibliometric analysis. Currently, the main databases commonly used for bibliometric analysis in the field of economics include Web of Science (WoS), Scopus, Google Scholar (GS), Microsoft Academic (MA), and Dimensions (Ardito et al., 2019). The main software tools commonly used to conduct bibliometric analysis include: CRExplorer , Publish or Perish , ScientoPyUI , Bibexcel , Biblioshiny, BiblioMaps , CiteSpace , CitNetExplorer , SciMAT , Sci2 Tool , VOSviewer (Moral-Muñoz et al., 2020).

MATERIALS & METHODOLOGY

The flowchart of article selection process applied in this study is summarized in Figure 1, which followed guidelines from previous publications (Dao et al., 2022). First, the authors searched all documents indexed in the Scopus database until December 2023, using "Nguyen Tat Thanh University" as one of the affiliations (n = 3523). Second, we excluded only two documents written in languages other than English. Third, we included only documents classified as articles, and excluded all documents belonging to other types, including 529 conference papers, 261 review papers, 69 book chapters, and 87 documents in other types. The remaining collection includes 2575 internal and international articles. Internal articles are defined as articles having all affiliations from Vietnam, while international articles are defined as articles having affiliations from Vietnam and at least another country. After removing 1070 internal articles, in the fourth step, the final collection include 1505 international articles which were the results of international collaboration between scholars from NTTU and other foreign colleagues. Fifth, metadata of this final collection was downloaded from the Scopus database to a comma-separated values (csv) file to be used as input data for our bibliometric analysis, using the two most popular software in this field: VOSviewer, a free Java tool (van Eck & Waltman, 2010) and Biblioshiny, open-source program written in the R environment (Aria & Cuccurullo, 2017). VOSviewer is very effective in constructing and visualizing large collaboration networks between scholars, institutions, as well as countries. Biblioshiny, on the other hand, is more useful in providing scientific statistic of the article collection, as well as executing science mapping of the literature. Each software has its own set of strengths and weaknesses; therefore, scholars often utilize them both in their biblimetric analysis to obtain a comprehensive overview of scientific development of a research direction or a research institution over time (Pham-Duc et al., 2020). Note that the search query string was conducted on March 5, 2024.

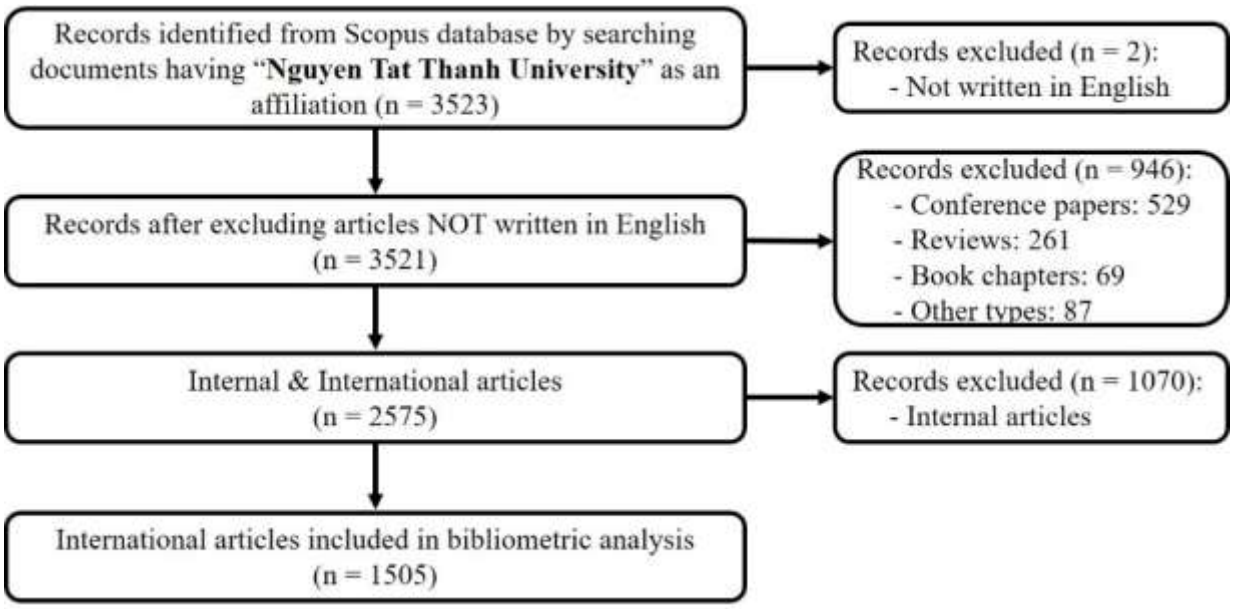

Figure 1. The flowchart of article selection process applied in this study.

RESULTS

General Statistic Information

According to our retrieved results, the first two international cooperation articles from NTTU were published in 2011 as the results of collaborations with colleagues from Korea, focusing on the field of electronics (Nguyen et al., 2011) and neural network (Huynh & Won, 2011). As seen in Figure 1, the development of international collaboration of NTTU can be divided into two periods, with 2018 as the turning point. From 2011 to 2018, the annual number of articles increased slowly (Figure 1 – bar chart), with a maximum of 57 articles in 2018. The total article published during this 8-year period was 134, which accounts for only 8.9% of the total collection of 1505 articles. During the 2019-2023 period, the annual number of publications rocketed, with at least 250 articles published every year. This number was nearly five time higher than the maximum annual number of the previous period. The second period accounts for 91.1% of the total collection (n = 1371). The pie chart in Figure 1 provides a detailed summary of the main research fields of the article collection using the classification results provided by the Scopus database (depending on the content, one article can be assigned automatically to one or several categories). The most number of articles (n = 437; 14.0%) are related to Environmental Science, followed by Chemistry (n = 378; 12.1%), Medicine (n = 331, 10.6%), and Engineering (n = 312; 10%). These four research fields account for nearly 50% of the collection. Materials Science (n = 261; 8.3%), Chemical Engineering (n = 244; 7.8%), Physics (n = 193; 6.2%), Biochemistry & Biology (n = 187; 6.0%), Energy (n = 155; 5.0%), Computer Sciences (n = 132; 4.8%), and Agricultural Sciences (n = 132; 4.2%) are in the next positions. Articles assigned to other research fields account for about 11.2% of the collection (n = 350).

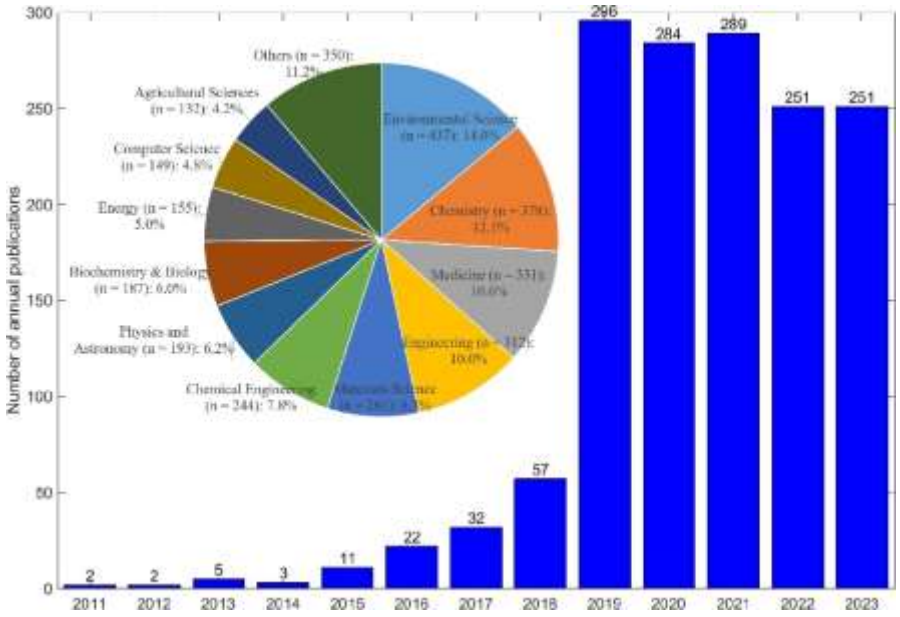

Figure 2. Bar chart illustrates the annual number of international collaboration articles of NTTU during the 2011-2023 period. Pie charts shows percentages of the top research disciplines in which these articles were classified. Note that the Scopus database assigns automatically each article into one or several research disciplines based on its content.

The publication collection was published in a total of 565 scientific journals, and at the time of this study, they received a total of 73,940 citations. A breakdown of citations counts is shown in Figure 3. There are 80 articles that received more than 100 citations (5.32%), 109 articles received 50-99 citations (7.24%). The majority of the collection received 20-49 citations (n = 322; 21.39%), 10-19 citations (n = 307; 20.40%), and 1-5 citations (n = 364; 24.19%). There are 196 articles (13.02%) received 6-9 citations, and 127 articles (n = 8.44%) haven't received any citation. Nearly 87% of uncited articles (n = 110) were published recently in 2022 and 2023. This is as expected because publications normally receive the first citation 24 months after their publication date (Nane, 2015).

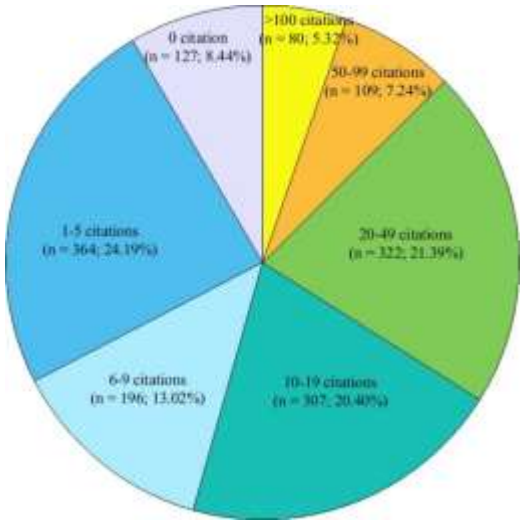

Figure 3. Distribution of the number and percentage of articles based on the total number of citations received at the time of this study.

International Collaboration of Nguyen Tat Thanh University at Country Level

Our results indicate that scholars from NTTU has international collaboration with scholars located in ninety other countries and territories (hereafter referred to as "countries" for simplification). Figure 4 shows the collaboration network between NTTU and the forty most popular partner countries with at least ten joint publications. Each node represents a country, with its size reflecting the quantity of publications. Countries are coded in different colors, and those sharing the same color belong to the same research cluster. Table shows detailed statistical numbers of the top fifteen most productive partner countries. Having contributed 411 articles and received 9740 citations, which make up 27.30% and 13.17% of the total articles and citations, respectively, Korea stands out as the only and most important and partner country within the first cluster (cyan). The second cluster (yellow) has four countries and all of them are listed in Table 3, including the USA (260 articles & 7753 citations), France (81 articles & 1845 citations), Singapore (224 articles & 5966 citations), and Thailand (77 articles & 1309 citations). India (186 articles & 8000 citations) is the only country of the third cluster (violet) being listed in Table 3. Other countries in this clusters are Canada and Chile. China, Malaysia, and Australia are the main contributors of the fourth cluster (green) as their numbers of articles and citations are much higher than the three other countries in this cluster (UK, Bangladesh and Macao. The fifth cluster (blue) also has six countries, with Taiwan (159 articles & 2586 citations) is the center of this group. Finally, the last cluster (red) includes twenty countries, but their contribution is quite limited compared to other clusters.

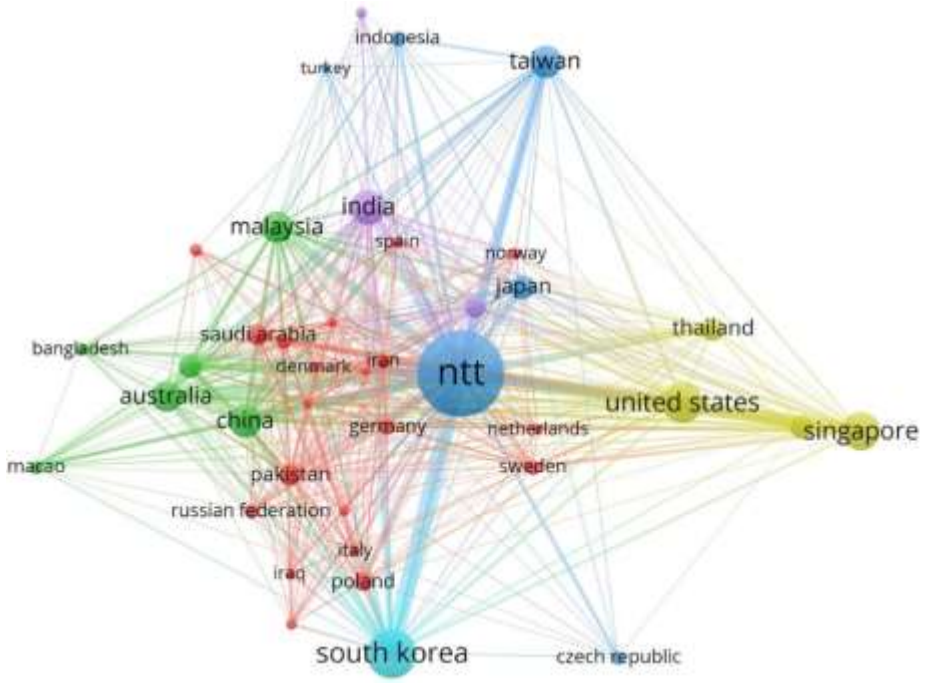

Figure 4. International collaboration network of NTTU and forty most popular partner countries. Each note represents a country with at least ten joint publications with NTTU. Countries coded in the same colors belong to the same collaboration network.

Table 3. The most productive partner countries with NTTU by number of articles and citations.

Order	Country	Cluster	Total articles	%	Total citations	%
1	Korea	1	411	27.30	9740 (#1)	13.17
2	USA	2	260	17.27	7753 (#3)	10.48
3	Singapore	2	224	14.88	5966 (#5)	8.06
4	India	3	186	12.35	8000 (#2)	10.72
5	China	4	169	11.22	6934 (#4)	9.37
6	Taiwan	5	159	10.56	2586 (#12)	3.50
7	Malaysia	4	150	9.96	5317 (#6)	7.19
8	Australia	4	142	9.43	4719 (#7)	6.38
9	France	2	81	5.38	1845 (#14)	2.50
10	Japan	5	78	5.18	2836 (#11)	3.83
11	Thailand	2	77	5.11	1309 (#15)	1.77
12	UK	4	72	4.78	2527 (#13)	3.41
13	Saudi Arabia	6	63	4.18	2949 (#10)	3.99
14	Canada	3	61	4.05	3540 (#8)	4.78

15	Pakistan	6	59	3.92	3066 (#9)	4.14

International Collaboration of Nguyen Tat Thanh University at Scholar Level

The collaboration network between the most productive researchers of NTTU and international scholars is shown in Figure 5. Similar to Figure 4, each node in Figure 5 represents a scholars, and the size of node is proportional to the number of articles. Scholars belong to the same research groups are identified and coded in the same colors. A total of 19 clusters are classified; however, there are three outstanding research groups which have the most significant impact on publication records of NTTU. The first research group (red) is formed around three permanent researchers of NTTU, namely Vo D.V.N., Bach L.G., and Nguyen T.D. The second research group (blue) is formed around Nguyen D.D., another permanent researcher of NTTU. The third research group is formed between the green, yellow and pink clusters, with the main contributors from Singapore (Ho R.C. and Ho C.S.H.), the USA (Latkin C.A.), Hanoi Medical University (Tran B.X.), Sweden (Nguyen L.H.), and NTTU (Vu G.T.). Notably, this research group has no collaboration with other research teams in NTTU. On the other hand, contribution of scholars in other clusters is quite limited compared to the impact of these three research groups.

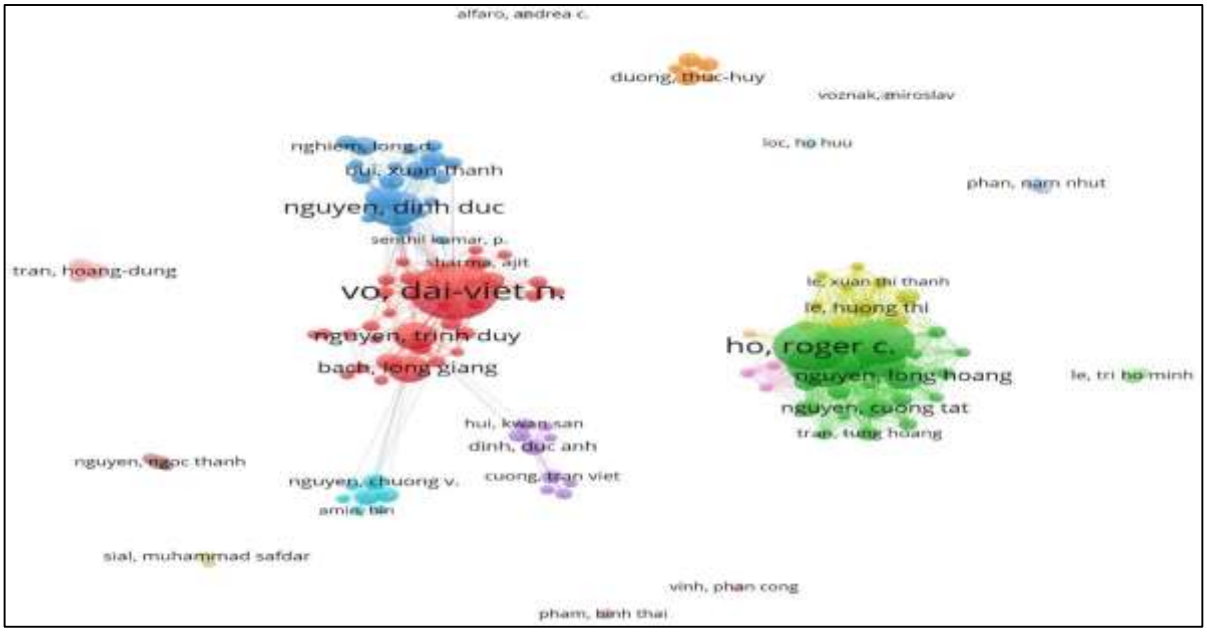

Figure 5. Collaboration network of internal and external scholars having at least 10 articles using NTTU as one of the affiliations.

Detailed statistics numbers of the most productive scholars in Figure 5 is shown in Table 4, along with addresses of their working institutions. Vo D.V.N published the most articles (n = 210), and received the most citations (n = 7571). Two scholars from Singapore are in the next two positions, namely Ho R.C. with 160 articles and 4020 citations, and Ho C.S.H. with 150 articles and 3611 citations. Tran B.X. and Latkin C.A. followed with 148 and 141 articles, and 3710 and 2826 citations, respectively. These four scholars are all key members of the third research group. In the sixth position is Nguyen D.D., the only scholar from the second research group, who published 99 articles and received 2355 citations. The last four positions were occupied by scholars from the first and the third research groups, namely Vu G.T. (85 articles and 1626 citations), Nguyen T.D. (65 articles and 1607 citations), Bach L.G. (63 articles and 1359 citations), and Nguyen L.H. (59 articles and 813 citations). In the top ten most productive scholars, five are permanent researchers of NTTU and five are from other institutions in Vietnam and foreign countries. Bach L.G. stands out as the only scholar with the first publication affiliated with NTTU since 2014. The first article using NTTU affiliation by Vo D.V.N. was published in 2017, whereas all other scholars listed in

Table just started using NTTU affiliation in 2018.

Table 4. The most productive scholars based on the number of articles and citations

Order	Author	Research group	Institution/Country	No. of articles	No. of citations
1	Vo D.V.N.*	1	Nguyen Tat Thanh University/ **Vietnam**	210	7571
2	Ho R.C.	3	National University of Singapore/ **Singapore**	160	4020
3	Ho C.S.H.	3	National University Hospital, **Singapore**	150	3611
4	Tran B.X.	3	Hanoi Medical University/ **Vietnam**	148	3710
5	Latkin C.A.	3	Johns Hopkins University/ **USA**	141	2826
6	Nguyen D.D.*	2	Nguyen Tat Thanh University/ **Vietnam**	99	2355
7	Vu G.T.*	3	Nguyen Tat Thanh University/ **Vietnam**	85	1626
8	Nguyen T.D.*	1	Nguyen Tat Thanh University/ **Vietnam**	65	1607
9	Bach L.G.*	1	Nguyen Tat Thanh University/ **Vietnam**	63	1359
10	Nguyen L.H.	3	Karolinska Institutet, **Sweden**	59	813

* Permanent researchers of NTTU

Analysis Of the Most Popular Journals

The list of fifteen scientific journals published the most number of papers from international collaboration of NTTU is shown in Table 5 with detailed information about the publishing house, number of citations received, the best Scopus's quartile of journals, and their current impact factor if available. There are seven journals belong to the Elsevier publishing house, three to the MDPI, while Springer, Taylor & Francis, IEEE, Royal Society of Chemistry and Academic Press Inc. each have only one journal. International Journal of Environmental Research and Public Health (IJERPH) and Chemosphere are in the first two positions, with outstanding number of articles (72 and 61), as well as number of received citations (2006 and 2356). The number of articles published in other journals in Table 5 is far less than in these two journals. Environmental Research is in the third position with 29 articles and 634 citations, and Science of the Total Environment is in the fourth position with 22 articles and 1073 citations. Three journals in the next positions published more than 20 articles, while the remaining eight journals published from 15 to 19 articles. Notably, The Lancet only published 17 articles, but received a total of 26,334 citations, which accounts for 35.61% of the total citations. All articles published in this journal focused on medical science with contributions from scientists from many countries. Of the fifteen most popular journals, six are open access, with three belonging to the MDPI publishing house. In total, all journals in Table published 394 articles and received 35,726 citations, which account for 26.18% and 48.31% of the total articles and citations of the collections, respectively. All journals belong to the first two Scopus quartile in their categories, with 10 Q1 journals and 5 Q2 journals.

The annual number of articles published by these fifteen journals during the 2018-2023 period is shown in Figure 5. Similar to the trend observed in Figure 2, the number of annual articles published in these journals in the second sub-period is much higher than the first sub-period. The most prominent point is the contrast in publication trends observed in the two most popular journals. The number of annual articles published in IJERPH decreased quickly over the years, from 45 articles published in 2019 to 18 in 2020, and only 3, 2, and 0 in the next three years. This decline trend can be explained by the fact that concerns have been raised to this journal about content relevance criterion, and the journal has been delisted from the WoS database by Clarivate (MDPI, 2023). On the other hand, the number of annual articles published in Chemosphere showed an increasing trend, from 4 articles in 2019 and 1 articles in 2020 to 19 in 2021 and 33 in 2022. However, there were only 4 articles published in this journal in 2023. For Molecules, another journal belonging to the MDPI publishing house, the annual publication trend shows similarity to IJERPH, with a maximum of 12 articles published in 2019, but decreased to only 1-2 articles in the next four years.

Table 5. List of journals published the most articles conducted by scholars from NTTU

Order	Journal/ Publishing House	No. of articles (%)	No. of citations (%)	Best Quartile*	Impact factor
1	International Journal of Environmental Research and Public Health/ **MDPI ****	72 (4.78)	2006 (2.71)	Q2	Delisted from WoS
2	Chemosphere/ **Elsevier**	61 (4.05)	2356 (3.18)	Q1	8.8
3	Environmental Research/ **Academic Press Inc.**	29 (1.92)	634 (0.85)	Q1	8.3
4	Science of the Total Environment/ **Elsevier**	27 (1.79)	1073 (1.45)	Q1	9.8
5	Environmental Technology and Innovation/ **Elsevier ****	22 (1.46)	346 (0.46)	Q1	7.1
6	Sustainability/ **MDPI ****	22 (1.46)	517 (0.69)	Q2	3.9
7	International Journal of Hydrogen Energy/ **Elsevier**	21 (1.39)	579 (0.78)	Q1	7.2
8	Fuel/ **Elsevier**	19 (1.26)	423 (0.57)	Q1	7.4
9	IEEE Access/ **IEEE ****	19 (1.26)	106 (0.14)	Q1	3.9
10	Molecules/ **MDPI ****	19 (1.26)	354 (0.47)	Q1	4.6
11	Journal of Environmental Chemical Engineering/ **Elsevier**	18 (1.19)	494 (0.66)	Q1	7.7
12	Natural Product Research/ **Taylor and Francis**	18 (1.19)	77 (0.1)	Q2	2.2
13	The Lancet/ **Elsevier**	17 (1.12)	26334 (35.61)	Q1	168.9
14	RSC Advances/ **Royal Society of Chemistry ****	15 (0.99)	291 (0.39)	Q2	3.9
15	Topics in Catalysis/ **Springer**	15 (0.99)	136 (0.18)	Q2	3.6

* According to Scimago Journal & Country Rank, accessed on 05 March, 2024
** Open Access journals, accessed on 05 March, 2024

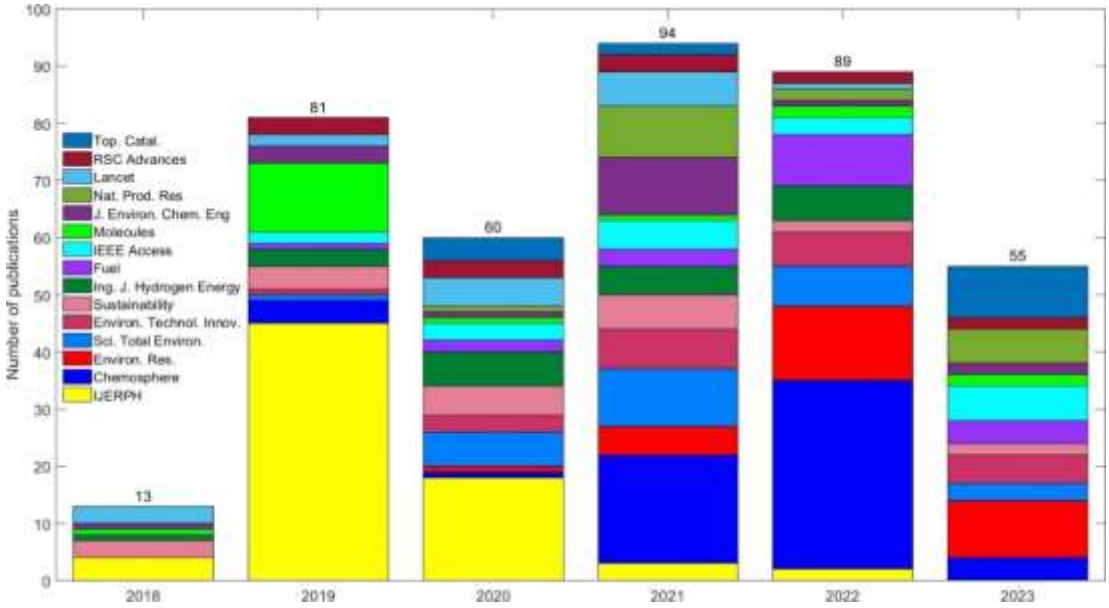

Figure 6. Annual number of articles published in journals listed in Table 3 during the 2018-2023 period.

Most Important Funding Sponsors of Nguyen Tat Thanh University

Moving on to the most important funding sponsors, Table 6 shows the list of the top ten sponsors for international research projects of NTTU. The most important sponsor of NTTU is the National Foundation for Science and Technology Development (NAFOSTED) of Vietnam who sponsored to 152 articles. National Research Foundation of Korea, who was being acknowledged in 90 articles, was in the second position. Other sponsors in the top ten provided much limited financial support: Bill and Melinda Gates Foundation (n = 51), Ministry of Science and Technology of Taiwan (n = 48), US National Institutes of Health (n = 43), Ministry of Science, ICT and Future Planning of Korea (n = 42), NTTU (n = 38), Australian National Health and Medical Research Council (n = 33), University of Technology Sydney (n = 31), and National Natural Science

Foundation of China (n = 31). In total, the top ten funding sponsors have been acknowledged in 446 articles that received 50,459 citations, which accounted for 29.63% of the total publications and 68.24% of the total citations of the collection, respectively.

Table 6. List of the most important funding sponsors

Order	Funding sponsors	Country	No. of articles
1	National Foundation for Science and Technology Development (NAFOSTED)	Vietnam	152
2	National Research Foundation of Korea	Korea	90
3	Bill and Melinda Gates Foundation	USA	51
4	Ministry of Science and Technology	Taiwan	48
5	National Institutes of Health	USA	43
6	Ministry of Science, ICT and Future Planning	Korea	42
7	Nguyen Tat Thanh University	Vietnam	38
8	National Health and Medical Research Council	Australia	33
9	University of Technology Sydney	Australia	31
10	National Natural Science Foundation of China	China	31

Analysis Of Most Cited Articles

List of the most cited articles in the publication collection is shown in

Table 7. Note that the authors decided to not include 14 most cited articles in the field of medical science to this analysis because they were all global analysis with inputs from hundreds of scholars in many countries, making the contribution of scholars from NTTU being insignificant. All these 14 articles were conducted by scholars from the third cluster in Figure 5. Being in the first position in

Table is an article focusing on autonomous concrete crack detection using neural network (Dung & Anh, 2019), with a total of 719 citations. In the second position, with 472 citations, is an article investigating the use of biomass waster for energy recovery and valorization (Foong et al., 2020). With 399 citations, the work about Quasi-Z-Source inverter secured the third position (Nguyen et al., 2011), followed by an article related to flood modelling using different machine learning methods with 382 citations (Khosravi et al., 2019). These are the four articles in

Table 7 which have received more than 300 citations at the time of this study. Other papers in

Table 7 received from 200 to 300 citations, focusing on different research directions, such as impact of Covid-19 on mental and physical health, and quality of life (Tran et al., 2020; Wang et al., 2021), systematic review of burnout symptoms among nurses (Woo et al., 2020), photocatalytic (Kumar et al., 2021), review on biosynthesis of metal nanoparticles (Saravanan et al., 2021), and meta-analysis of global lifetime (Lim et al., 2019). The total number of citations of these ten articles is 3501, which corresponds to 4.73% of the total citation of the collection. If we excluded the number of citations of the 14 excluded articles (n = 10,133), the contribution of ten articles in

Table 7 increases to 5.48%. Among the ten articles, six were published in journals belonging to the Elsevier publishing house, while IEEE, MDPI, Frontiers, and Public Library of Science, each publishing house published one paper. Except for the third article published in 2011, in which author Nguyen M.K. was the main author, the main authors of all nine other articles were not from NTTU (main authors are defined as the first or the corresponding author). Vo D.V.N. was the only scholar who was co-author of three articles, while Vu G .T. and Ho R.C. each contributed to two articles listed in

Table 7.

Table 7. List of articles conducted by scholars from NTTU received the most number of citations.

Title	Authors	Journal/ Publishing House	Main authors from NTTU *	Co-authors from NTTU	No. of citations	Year
Autonomous concrete crack detection using deep fully convolutional neural network (Dung & Anh, 2019)	Cao V.D. & Le D.A.	Automation in Construction/ **Elsevier**	No	Le D.A.	719	2019
Valorization of biomass waste to engineered activated biochar by microwave pyrolysis: Progress, challenges, and future directions (Foong et al., 2020)	Foong, S. Y., Liew, R. K., Yang, Y., Cheng, Y. W., Yek, P. N. Y., Wan Mahari, W. A., Lee, X. Y., Han, C. S., Vo, D.-V. N., Van Le, Q., Aghbashlo, M., Tabatabaei, M., Sonne, C., Peng, W., & Lam, S. S.	Chemical Engineering Journal/ **Elsevier**	No	Vo D.V.N.	472	2020
Switched-Inductor Quasi-Z-Source Inverter (Nguyen et al., 2011)	Nguyen, M.-K., Lim, Y.-C., & Cho, G.-B.	IEEE Transactions on Power Electronics/ **IEEE**	Yes Nguyen M.K.	N/A	399	2011
A comparative assessment of flood susceptibility modeling using Multi-Criteria Decision-Making Analysis and Machine Learning Methods (Khosravi et al., 2019)	Khosravi, K., Shahabi, H., Pham, B. T., Adamowski, J., Shirzadi, A., Pradhan, B., Dou, J., Ly, H.-B., Gróf, G., Ho, H. L., Hong, H., Chapi, K., & Prakash, I.	Journal of Hydrology/ **Elsevier**	No	Ho H.L.	382	2019
The impact of COVID-19 pandemic on physical and mental health of Asians: A study of seven middle-income countries in Asia (Wang et al., 2021)	Wang et al	Plos One/ **Public Library of Science**	No	Vu G.T.	298	2021
Global prevalence of burnout symptoms among nurses: A systematic review and meta-analysis (Woo et al., 2020)	Woo, T., Ho, R., Tang, A., & Tam, W.	Journal of Psychiatric Research/ **Elsevier**	No	Ho R.C. & Tam W.	289	2020
Construction of dual Z-scheme g-C3N4/Bi4Ti3O12/Bi4O5I2 heterojunction for visible and solar powered coupled photocatalytic antibiotic degradation and hydrogen production: Boosting via I−/I3− and Bi3+/Bi5+ redox mediators. (Kumar et al., 2021)	Kumar, A., Sharma, G., Kumari, A., Guo, C., Naushad, M., Vo, D.-V. N., Iqbal, J., & Stadler, F. J.	Applied Catalysis B: Environmental/ **Elsevier**	No	Vo D.V.N.	247	2021
A review on biosynthesis of metal nanoparticles and its environmental applications (Saravanan et al., 2021)	Saravanan, A., Kumar, P. S., Karishma, S., Vo, D.-V. N., Jeevanantham, S., Yaashikaa, P. R., & George, C. S.	Chemosphere/ **Elsevier**	No	Vo D.V.N.	242	2021
Global Lifetime and 12-Month Prevalence of Suicidal Behavior, Deliberate Self-Harm and Non-Suicidal Self-Injury in Children and Adolescents between 1989 and 2018: A Meta-Analysis (Lim et al., 2019)	Lim, K.-S., Wong, C. H., McIntyre, R. S., Wang, J., Zhang, Z., Tran, B. X., Tan, W., Ho, C. S., & Ho, R. C.	International Journal of Environmental Research and Public Health/ **MDPI**	No	Ho R.C.	230	2019
Impact of COVID-19 on Economic Well-Being and Quality of Life of the Vietnamese During the National Social Distancing (Tran et al., 2020)	Tran, B. X., Nguyen, H. T., Le, H. T., Latkin, C. A., Pham, H. Q., Vu, L. G., Le, X. T. T., Nguyen, T. T., Pham, Q. T., Ta, N. T. K., Nguyen, Q. T., Ho, C. S. H., & Ho, R. C. M.	Frontiers in Psychology/ **Frontiers**	No	Vu G.L.	223	2020

* Main authors are defined as the first or the corresponding authors, and used email address from NTTU for the submission

Keyword Analysis

The word clouds of 186 most popular author keywords which appeared at least four times in the publication collection is shown in Figure 7. More popular and important keywords are displayed bigger and placed closer

to the center of the word clouds. Vietnam appears to be the biggest one, which suggests that the main study area of the majority in the article collection is Vietnam. Wastewater treatment is the second, and adsorption is the third most popular keywords. Other important ones can be identified, for example, syngas, hydrogen, photocatalysis, scientometrics, machine learning, response surface methodology, and HIV/AIDS.

Although being able to show the most important keywords, a word clouds cannot visualize the connection between them; therefore, a co-occurrence network of these keywords is illustrated in Figure 8 to clearly mapping the relationship between these keywords. Similar to other networks in Figure 4 and Figure 5, each node represents a keyword, and keywords belonging a cluster are displayed in the same colors and placed closer in the map. A total of fourteen clusters can be identified, representing the main international research topics of NTTU. Most of research focusing on Vietnam is related to medical science, investigating on some direction such as breast cancer, covid-19, pregnant women, and HIV/AIDS. These are the main research directions of scholars in the third research group in Figure 5. The research teams focusing on wastewater treatment, adsorption, and photocatalysis worked closely, and are the research directions of the first research group in Figure 5. In addition, there is another research direction focusing on different aspects of the Mekong Delta, such as flood dynamics, salinity instruction, arsenic-contaminated groundwater, and micro plastics using neural network and deep learning algorithms, as represented by keywords in the purpose cluster.

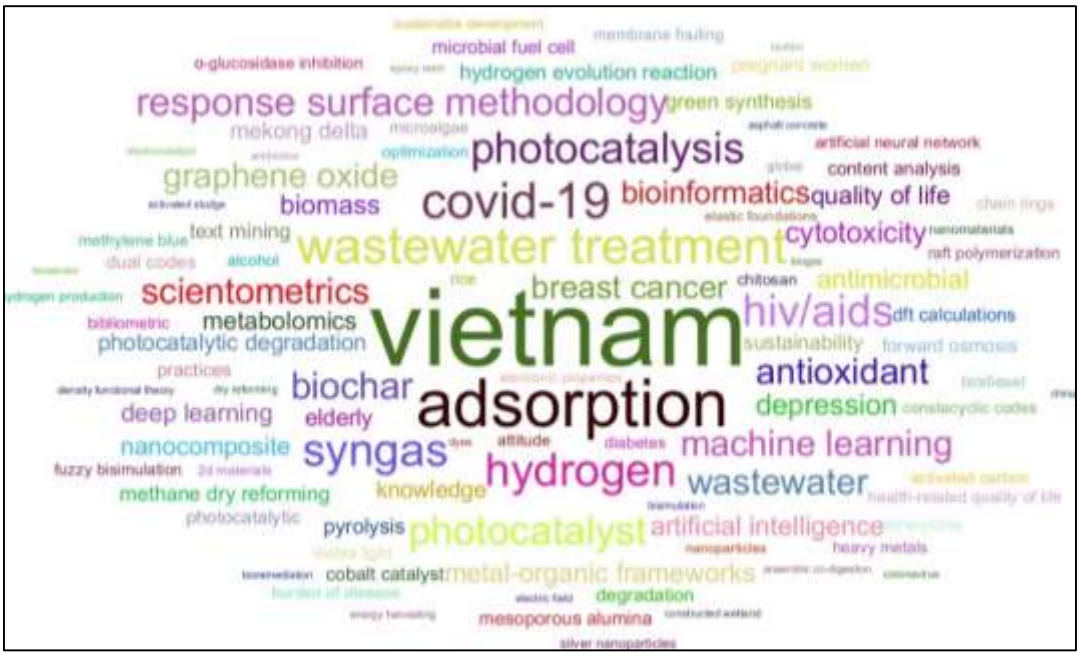

Figure 7. Word clouds of 186 most popular author keywords which appeared at least 4 times in the publication collection.

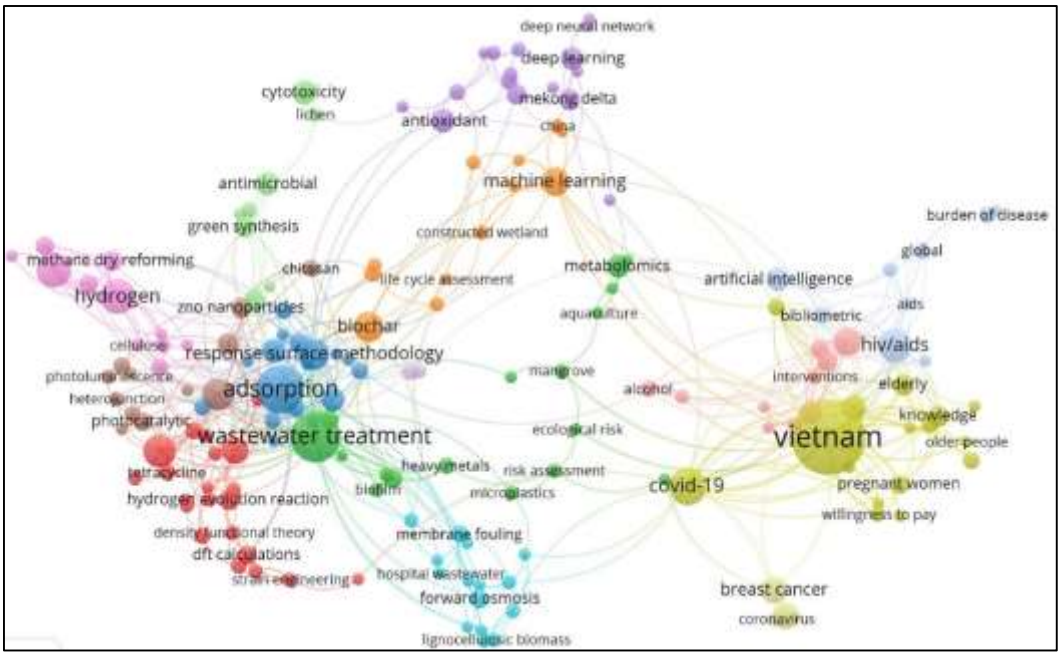

Figure 8. The co-occurrence network of most popular author keywords presented in Figure 7.

DISCUSSIONS

The analysis results indicate a significant increase in the number of collaborative publications by NTTU since 2018 (Figure 2), which aligns well with the research practices of NTTU. As demonstrated in Table 1 and Table 2, NTTU has shown an increasing interest in enhancing international collaboration through projects, conferences, seminars, and research collaboration groups through cooperative projects with the UK, the US, Spain, etc. Through the implementation of collaborative projects and international conferences, faculty members at NTTU have the opportunity to interact and collaborate with researchers from around the world to produce research outputs. Since 2016, there have been 06 international cooperation agreements signed between NTTU and the Institute of Chartered Accountants in England and Wales (ICAEW), the Asian Institute of Technology, the French University Agency for Francophonie (AUF), ASIA SAFE – ERASMUS+, Velo Tarnovo University (Bulgaria), Josai International University (Japan) (Table 1), and 07 international cooperation projects with universities and research institutes in the UK (Birmingham University), University of Padova (Italy), University of Salamanca (Spain), University of East Anglia (UK), British Council, Northeast Normal University (China), Universitas Negeri Yogyakarta (UNY), etc. This is evident in the countries that collaborate with NTTU to publish more than 10 papers (Figure 4), with some countries demonstrating good collaboration in research, such as the US, Japan, and several Asian countries like South Korea. However, Figure 4 also shows that some universities have signed cooperation agreements with NTTU early on, but the collaboration in publications is not significant, only limited to research collaboration projects, such as the UK, Bulgaria, Germany, etc.

The research collaboration between scientists at NTTU and those from around the world is reflected in the collaboration network, which is not yet extensive. Only three main research groups at NTTU have been clearly formed (Figure 5), led by some scientists who collaborate with researchers from the US, South Korea, the Philippines, Japan, focusing on medical and health sciences, environmental sciences, and materials science. This is consistent with the current training and research practices at NTTU, as these three fields were among the first established at the university, so faculty members and researchers in these fields have the most experience and expertise at NTTU. Consequently, there are many publications in these three areas, and experienced researchers frequently engage in international collaboration in scientific publications. However, Figure 5 shows that out of the three groups, two groups led by external researchers collaborate with scientists worldwide in

researching health and environmental sciences, while the third group on materials science is led by an external researcher to connect, collaborate, and publish. This demonstrates the flexible research model at NTTU, where the university funds research projects for both internal and external researchers to study NTTU's development. Therefore, for newly established fields with fewer faculty members and less experience, NTTU invites reputable external researchers in those fields to carry out projects with faculty members at NTTU to improve research quality and transfer experience to NTTU researchers.

Since 2021, after issuing regulations on international cooperation, NTTU has also changed its research direction with the principle of developing internal research capacity from university researchers to achieve sustainability in research product development. Therefore, fewer external researchers will participate in international publications compared to university staff, explaining the unstable number of publications annually and the decreasing trend from 2020 to the present (Figure 2). The analysis of the top 10 most cited researchers in Table 5 shows that these authors belong to the third collaboration group (blue color - Figure 5), all of whom are external researchers to NTTU, collaborating in research with NTTU. This indicates that NTTU has not yet owned or attracted strong researchers. Additionally, keyword analysis in Figures 7 and 8 reveals that NTTU's international research and publication directions are quite diverse and not focused on specific core research areas (beyond the three fields of health sciences, environmental sciences, and materials science).

To develop an international cooperation model in general and collaboration in research and scientific publications in particular, NTTU needs to change its training strategy to enhance the research capacity of researchers within the university. The university should implement international cooperation agreements with foreign universities, organize faculty exchange programs, and regularly host international scientific conferences and seminars to help faculty members enhance their awareness and research capacity and publish internationally.

CONCLUSION

This study investigates the main characteristics of scientific articles resulting from international collaborations between NTTU and scholars from other countries over the last decade. Bibliometric analysis has been done to analyze metadata of 1505 articles indexed in the Scopus database during the 2011-2023 period. Results show that the publication record of international collaboration of NTTU can be divided into two sub-periods: before 2018 which accounts for only about 9% of the total publication, and after 2018 which accounts for more than 91%. Scholars from Korea, the USA and Singapore have the biggest contribution of the international collaboration of NTTU, while contribution of scholars from other countries is much less significant. Only three strong research groups are identified, centering on some permanent scientists of NTTU such as Vo D.V.N., Nguyen D.D., Vu G.T., Nguyen T.D., and Bach L.G., and on some inviting scholars, for instance Ho R.C. and Ho C.S.H. from Singapore, Tran B.X. from Hanoi Medical University, and Latkin C.A. from the USA. As a consequence, the number of strong research directions is also limited, only focusing on some research topics of the three groups, including medical science, wastewater treatment, adsorption, and photocatalysis. All 14 most cited articles are in the field of medical science with hundreds of co-authors, making contribution of NTTU being very limited. When excluding these articles, the main authors of nine over ten most cited articles in other research fields were not permanent scientist of NTTU.

This study clearly shows the main features of scientific output of NTTU resulting from international collaboration. However, it has some major limitations. First, the authors only used metadata from the Scopus database for this analysis. Scopus database alone does not fully cover all international collaboration publications from NTTU. However, the authors cannot merge metadata from several bibliographic databases (for example, WoS, Google Scholar, or PubMed) because of the technical limitations of these two softwares used in this work. Second, data correction has been done manually by scanning the whole publication collection, but it was not perfect, especially with author names and their main affiliations. Errors might occur in our analysis, but it does not strongly affect to the final results.

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