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Highly Cited Publications of Selected Indian Institutes of Technology (IITs): A Bibliometric Study

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Abstract

The study highlights the highly cited publications published by selected five Indian Institutes of Technology (IITs) during the period 2010-2020. The IITs are the institutes of eminence and produced the quality scholarly output. They always occupy top positions in the ranking of institutions by different agencies. The data has been collected from the Essential Science Indicator (ESI) which is a tool of Web of Science database. A total of 468 highly cited articles have been downloaded and analysed. The various parameters considered for the study are the year-wise distribution of articles, subject-wise distribution; the renowned journals published these articles, and top-cited articles. The findings revealed that IIT-M has a larger amount of immensely cited articles, and the chosen IITs have followed the collaborative model of more than four authors. Chemistry, Physics, and Engineering are the subjects in which the hugely cited articles have been published. The study would assist the researchers, academicians and funding agencies in providing a general overview of the highly cited articles produced by IITs and also in identifying the trend in research.

Keywords: Highly cited articles, Indian Institute of Technology-Madras (IIT-M), Indian Institute of Technology-Bombay (IIT-B), Indian Institute of Technology-Roorkee (IIT-R), Indian Institute of Technology-Delhi (IIT-D), Indian Institute of Technology-Kharagpur (IIT-KGP), ranking, research output, Bibliometric

1. Introduction

The place of India's higher education system in the world is at the third position while the University Grants Commission has been striving to provide policy framework and accreditation for higher education. The expansion of education in the shape of 20,000 colleges serving more

than 8 million students with the support of 800 universities as categorized (Central, State, Deemed, and Private Universities), including various Institutes of National Importance in various technological disciplines. The emphasis on science and technology through institutions since 2004 by the inclusion of distance learning and open education has been influential. With the great initiative of “Rashtriya Uchchar Shiksha Abhiyan (RUSA),” the government has provided promises and proper framework for state universities for better learning and research by promoting innovation. RUSA is a centrally sponsored program meant to encompass upgrading libraries, ICT infrastructure, etc. The RUSA scheme has focused upon the components such as access, equity, excellence, and exploration, with the objectives to “improve the overall quality of state institutions by ensuring conformity to prescribed norms and standards and adopt accreditation as a mandatory quality assurance framework” and induce transformative reforms, adequate availability of quality faculty, expand the institutional base, and “improve equity in higher education by providing adequate opportunities of higher education” to all classes from the society (Rashtriya Uchchar Shiksha Abhiyan, 2020).

1.1 The National Institutional Ranking Framework (NIRF) and Institutes of Technology

The National Institutional Ranking Framework (NIRF) is the initiative that was launched by MHRD (Ministry of Human Resource Development) on 29th September 2015 to provide a methodology to compare and rank various higher education institutions in India (NIRF Ranking Metrics, 2017). NIRF functions through the methodology in the shape of recommendations given by a Core Committee for identification of the broad parameters for ranking covering the “Teaching, Learning and Resources,” “Research and Professional Practices,” “Graduation Outcomes,” “Outreach and Inclusivity,” and “Perception.” This year, NIRF Indian Rankings for Indian institutes were announced on June 20th, 2020 due to delay by Covid-19 crisis (<https://twitter.com/DrRPNishank/status/1270968707024470018>). The ranking (NIRF Rankings, 2020) shows various institutions at their places such as IISc Bengaluru has been ranked at first place in the overall ranking and Jawaharlal Nehru University is at the second place while Banaras Hindu University is at the third place in the top universities list (NIRF Rankings, 2020). In the Institution sector as previously, IITs have reflected their strong position in the list as IIT Madras (IIT-M) has emerged as the best, which has been followed by IIT Delhi (IIT-D) and IIT Bombay (IIT-B) at second and third places in the ranking (Technical Education, 2020). NIRF rankings have been based on various categories, which have been increased from four (in 2016) to nine till times. There has been another framework for ranking in 2019 by MHRD as “Atal

Ranking of Institutions for Innovation Achievements or ARIIA rankings.” The parameters in NIRF rankings –are including “Teaching, Learning and Resources, Research and Professional Practices, Graduation Outcomes, Outreach and Inclusivity, and Perception” for criteria. It is great to observe that India’s higher education system has been considered as kind of most extensive in the world (first China and second, United States), categorically in the engineering education sector. In 1961, the Indian Parliament declared the institutes of technology as “institutes of national importance” by identifying their contribution to national growth and supporting these institutions to develop technological reputations (Best Universities in India, 2020).

a. Comparing Rankings of IITs and Few Universities

The rankings of Institutes of Technology and University have always been a matter of curiosity and education growth. It gives a chance to understand the differences and outputs in research as IIT Madras (score 85.31), IISc (score 84.18), and IIT Delhi (score 81.33) are ranked first, second and third; followed by IIT Bombay (score 80.75), IIT Kharagpur (score 75.85). In comparison to score of IITs, the ranking of JNU, New Delhi is 8 (score 68.78); BHU, Varanasi is ranked at 10 (score 62.03), and Calcutta University is ranked at 11 (with the Score 61.01) (India Rankings 2020: University; DMIR, 2020).

A: India Rankings 2020

| Name | City | State | Score | Rank |
|--|-----------|---------------|-------|------|
| Indian Institute of Technology Madras | Chennai | Tamil Nadu | 85.31 | 1 |
| Indian Institute of Science | Bengaluru | Karnataka | 84.18 | 2 |
| Indian Institute of Technology Delhi | New Delhi | Delhi | 81.33 | 3 |
| Indian Institute of Technology Bombay | Mumbai | Maharashtra | 80.75 | 4 |
| Indian Institute of Technology Kharagpur | Kharagpur | West Bengal | 75.85 | 5 |
| Indian Institute of Technology Kanpur | Kanpur | Uttar Pradesh | 74.99 | 6 |
| Indian Institute of Technology Guwahati | Guwahati | Assam | 68.81 | 7 |
| Jawaharlal Nehru University | New Delhi | Delhi | 68.76 | 8 |

| Name | City | State | Score | Rank |
|--|----------|---------------|-------|------|
| Indian Institute of Technology Roorkee | Roorkee | Uttarakhand | 68.48 | 9 |
| Banaras Hindu University | Varanasi | Uttar Pradesh | 62.03 | 10 |
| Calcutta University | Kolkata | West Bengal | 61.01 | 11 |
| Jadavpur University | Kolkata | West Bengal | 60.77 | 12 |

Source: India Rankings 2020: University

Table A: India Rankings 2020: observing the comparative status of IITs and top ranking universities

B. List of top 10 India Rankings 2020 is as follows:

| Sl. No. | Name of Institute | Rank No. |
|---------|--|----------|
| 1 | Indian Institute of Technology Madras | 1 |
| 2 | Indian Institute of Science, Bengaluru | 2 |
| 3 | Indian Institute of Technology Delhi | 3 |
| 4 | Indian Institute of Technology Bombay | 4 |
| 5 | Indian Institute of Technology Kharagpur | 5 |
| 6 | Indian Institute of Technology Kanpur 6 | 6 |
| 7 | Indian Institute of Technology Guwahati | 7 |
| 8 | Jawaharlal Nehru University, New Delhi 8 | 8 |
| 9 | Indian Institute of Technology Roorkee | 9 |
| 10 | Banaras Hindu University, Varanasi | 10 |

Source: <https://twitter.com/DrRPNishank/status/1270968707024470018>

Table B: List of top 10 India Rankings 2020

1.2 Rankings, Enrollments and Research Relations

Though the past few years have witnessed the proliferation of professional colleges, yet the most popularly admitted program is the three-year degrees in arts, commerce, and sciences. The rapid expansion since 2001 has given opportunities in the growth of higher education institutions (HEIs) as it is one of the largest systems across the globe, reflecting the number of 51,649 institutions. “According to the All India Survey on Higher Education (AISHE), India’s GER was 27.4 percent for 2017-18. At present, the paper says, the higher education sector in India consists of 3.74 crore students across 993 universities, 39,931 colleges, and 10,725 stand-alone institutions, according to the AISHE-2019”. With the gross enrolment ratio (GER) last financial

time segment (2018-19) was 26.3% with the target of securing 32% GER by 2022 by MHRD, India (Sharma, K., 2020; Ravi, S., Gupta, N. and Nagaraj, P., 2019).

The Central Advisory Board of Education (CABE) has been responsible and the highest advisory body to figure out the requisites and measurements. In this context, the National Knowledge Commission (2006) Report has induced the fresh insights with a reform agenda and the “committee on renovation and rejuvenation of higher education (Yashpal Committee)” provided the suggestions to protect and preserve the “intellectual autonomy” among the technological institutions. The creation of the “National Commission for Higher Education and Research (NCHER)” would guide the higher education institutions as research an important pillar (MHRD Policy Initiatives, 2020). The University Grants Commission (UGC) and Draft New Education Policy, 2019 have taken many initiatives and emphasis upon the reforms in the shape of intellectual output enhancing the environment (New Education Policy, 2019). Such ambiance is created by facilitating awareness, access, and affiliation with research output, which in itself is possible due to academic journals, research innovation, and output (Sharma, S. and Sharma, P., 2015).

The research and innovation provides the creation of globally relevant intellectual ecosystem at the national and international level in the form of citations received by the research produced. The industry linkages with the institutions in the shape of research and innovation have been measured with the view to amplify quality research (Sheikh, Y.A., 2017). During the last three decades, it is observed that funding by the government has been motivating on the sources other than the regular funding as “Union funding” has been changed to let the central higher education institutional to flourish (Ravi, S., Gupta, N. and Nagaraj, P., 2019). The Indian higher education sector has been observing various facets such as responsibilities, innovation and creativity, and research impact and measurements.

A belief that prevails in the sciences is that “highly cited articles reflect better quality research, and this position is well supported in the scientific literature” (Antonakis, J., and Lalive, R., 2008; Bergh, D. D., Perry, J. and Hanke, R, 2006; Lokker, et al., 2008). “Citations reveals the substantive relevance that the cited article has for a particular article and are not merely done in passing” (Baldi, S., 1998). The highly cited articles have a strong impact on the scholars as they are the trend-setters in their fields. The highly cited articles are different from ‘ordinary’ cited articles. The present study has selected the five IITs that are included in the list of top 10 India Rankings 2020. It will give the researchers, academicians, administrators and scientists an

impression on the scholarly output produced by the institutes of national importance. This study has analysed the data of highly cited articles published by the IITs in various subjects.

2. Related Literature

Indian Institutes of Technology (IITs) are known for the scholarly output published in various journals. The quality of research produced by the IITs is of international fame and acclaimed world wide. Hui, *et al.* (2020) performed a comprehensive analysis of the trend in the research output of premature ejaculation across the world. The study disclosed that Journal of Sexual Medicine published the highest number of publications. The highest co-citations were from Waldinger MD. Sweileh (2020), evaluated the research activity on climate change and health with a focus on infectious disease. The study observed that four themes were covered in the related literature: (1) climate change and infectious diseases; (2) climate change, public health and food security; (3) heat waves, mortality, and non-communicable diseases; and (4) climate change, air pollution, allergy, and respiratory health. The articles published on infection-related literature have the highest h-index than other documents. Iftikhar, *et al.* (2019), evaluated the importance and impact of articles that have been published entitled “gestational diabetes mellitus (GDM) in the specialty of obstetrics & gynecology and endocrinology” during the period 1946-2019. The study revealed that the researchers and funding institutions are now concentrating more on GDM.

Noorden, Maher, & Nuzzo (2014) explored the most cited research in the Nature journal. The top 100 papers were considered for the study and 3 papers have received more than 100,000 citations which lead the list of most cited literature. Mao, Wang, & Ho (2010), in their study evaluated the scientific production of risk assessment research across the globe, majority of the articles were published in English language. The enhancement of number of articles in this field ranges from 1 in 1968 to 1037 in 2007.

3. Objectives

The study has formulated several objectives, and based on that, data tabulation has been done.

The following are the objectives of the study:

- To analyse the total number of highly cited articles published by selected IITs
- To examine the year-wise distribution of immensely cited articles
- To examine the collaborative pattern followed in the published articles
- To find out the subjects in which the enormously cited articles are published

- To identify the renowned journals that have published the highly cited articles
- To identify the top highly cited articles among all the selected articles

4. Methodology

In this study, a bibliometric method has been applied to evaluate the highly cited articles published by selected five Indian Institutes of Technology (IITs) during the year 2010-2020 and provide insights into the quality of scholarly material. Bibliometric analysis is a statistical tool to map the trend or growth in a particular field. To conduct the study, the data has been collected from the Essential Science Indicator (ESI) a tool in Web of Science (Webofknowledge.com), a bibliographical database. ESI is an analytical tool that assists in identifying the top performing research in Web of Science Core Collection. It spotlights the emerging science trends as well as the influential authors, organizations, journals, countries, etc. The institutions were identified in the list available in ESI and downloaded. The immensely cited articles published by the five IITs have been separately downloaded in CSV format. Further, the collected data has been organized and tabulated to meet the objectives of the study.

5. Data analysis & Interpretation

The data for the enormously cited articles published by selected five IITs have been tabulated and analyzed to meet the objectives laid down for the study.

5.1 Research output of highly cited publications of five IITs

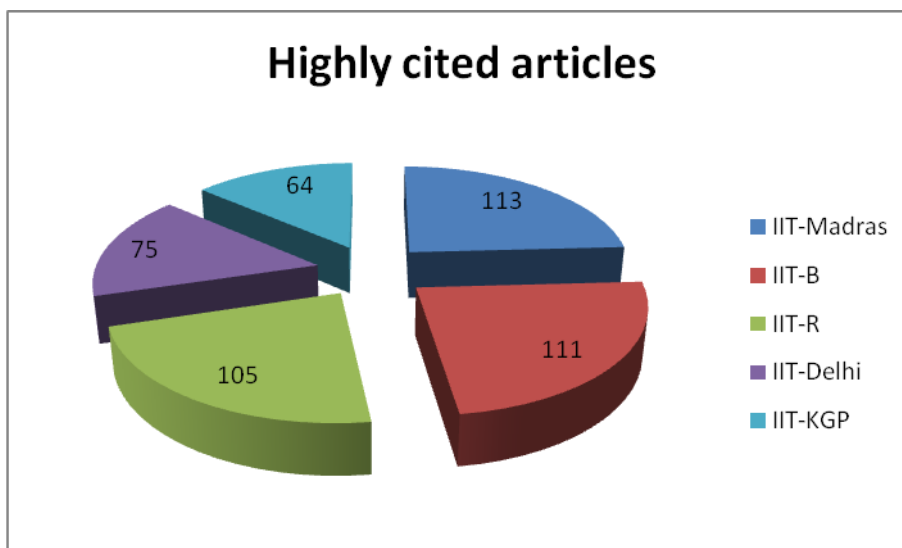
Table 1 depicts the total highly cited articles from the five IITs selected that are of national importance for the study. A total of 468 articles have been found cited highly. It has been observed from the table that in IIT-M 113(23.1%) articles are highly cited, followed by 111(23.7%) articles from IIT-B and 105(22.4%) articles from IIT-R. 75(16.0%) articles have been cited heavily in IIT-D, whereas in IIT-KGP, there are 64(13.6%) articles.

Table-1. Total output of highly cited articles

| Institutions | Highly cited articles | % |
|---------------------|------------------------------|----------|
| IIT-Madras | 113 | 23.15 |
| IIT-B | 111 | 23.71 |
| IIT-R | 105 | 22.43 |

| | | |
|-----------|-----|-------|
| IIT-Delhi | 75 | 16.02 |
| IIT-KGP | 64 | 13.67 |
| Total | 468 | |

Figure-1. Total output of highly cited articles



5.2 Year Wise highly cited articles

The year-wise distribution of highly cited articles from the selected five IITs has been portrayed in the table 2. It is found that in the year 2017, 26(23.0%) articles are cited highly, followed by in 2018 with 21(18.5%) and 20(17.6%) articles from IIT-M in the year 2019. In the years 2014 & 2015, only 4 (3.5%) articles are cited greatly. In IIT-B, 19(17.1%) articles are cited vastly in 2013 and 2017 whereas only 4 (3.6%) articles in 2012. 16(15.2%) articles are immensely cited in the year 2012 and 13(12.3%) articles during the year 2014-2016 in the IIT-R. Only 2(1.9%) articles have received a smaller amount of citations in the year 2018. IIT-D has published 10 (13.3%) articles each that are enormously cited in 2013, 2016, and 2017. During the years 2015 and 2016-2019, 8 (12.5%) articles each are immensely cited, whereas 3 (4.6%) articles each received a smaller amount of citations in the years 2011 and 2012.

Table-2. Year-wise highly cited articles

| Year Wise | No. of articles |
|-----------|-----------------|
|-----------|-----------------|

| | IIT-M | % | IIT-B | % | IIT-R | % | IIT-D | % | IIT-KGP | % |
|--------------|--------------|----------|--------------|----------|--------------|----------|--------------|----------|----------------|----------|
| 2010 | 6 | 5.3 | 7 | 6.3 | 9 | 8.5 | 2 | 2.6 | 6 | 9.3 |
| 2011 | 10 | 8.8 | 12 | 10.8 | 12 | 11.4 | 7 | 9.3 | 3 | 4.6 |
| 2012 | 5 | 4.4 | 4 | 3.6 | 16 | 15.2 | 7 | 9.3 | 4 | 6.2 |
| 2013 | 5 | 4.4 | 19 | 17.1 | 8 | 7.6 | 10 | 13.3 | 6 | 9.3 |
| 2014 | 4 | 3.5 | 11 | 9.9 | 13 | 12.3 | 5 | 6.6 | 6 | 9.3 |
| 2015 | 4 | 3.5 | 6 | 5.4 | 13 | 12.3 | 5 | 6.6 | 8 | 12.5 |
| 2016 | 7 | 6.1 | 7 | 6.3 | 13 | 12.3 | 10 | 13.3 | 4 | 6.25 |
| 2017 | 26 | 23.0 | 20 | 18.0 | 7 | 6.6 | 10 | 13.3 | 8 | 12.5 |
| 2018 | 21 | 18.5 | 12 | 10.8 | 2 | 1.9 | 7 | 9.3 | 8 | 12.5 |
| 2019 | 20 | 17.6 | 10 | 9.0 | 9 | 8.5 | 6 | 8.0 | 8 | 12.5 |
| 2020 | 5 | 4.4 | 3 | 2.7 | 3 | 2.8 | 6 | 8.0 | 3 | 4.6 |
| Total | 113 | | 111 | | 105 | | 75 | | 64 | |

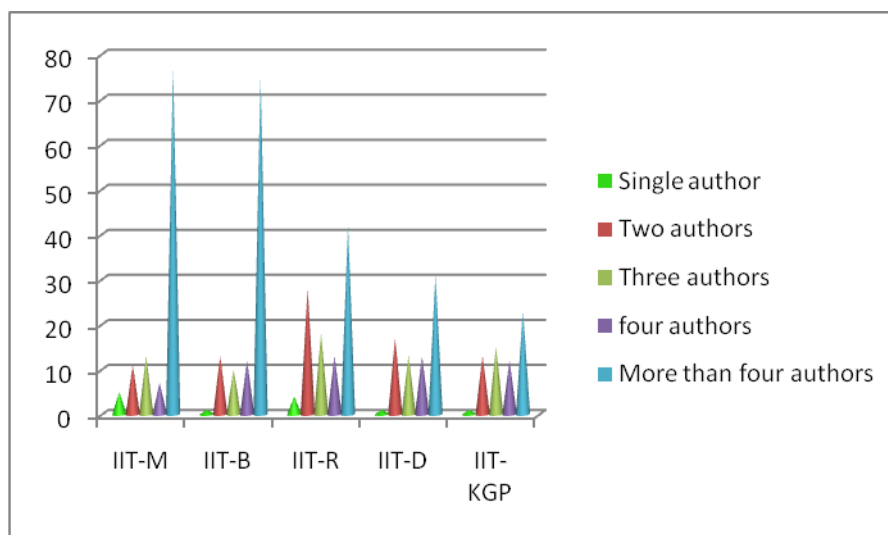
5.3 Collaboration pattern of the highly cited articles

Table 3 reveals the collaboration pattern followed in the highly cited articles. It is evident from the table that as the collaboration increases; the numbers of articles are also increasing consistently. 77 (68.1%) articles are published by more than four authors, followed by IIT-B with 75(67.5%), 42(40.0%) by IIT-R. In IIT-D and IIT-KGP, the collaborative model of more than four authors has produced 31(41.3%) and 23(35.9%), respectively. It is found that IITs believed in collaborative and partnership research work rather than an individual publication.

Table-3. Collaboration pattern of highly cited articles

| Authorship Pattern | IIT-M | % | IIT-B | % | IIT-R | % | IIT-D | % | IIT-KGP | % |
|---------------------------|--------------|----------|--------------|----------|--------------|----------|--------------|----------|----------------|----------|
| Single author | 5 | 4.4 | 1 | 0.9 | 4 | 3.8 | 1 | 1.3 | 1 | 1.5 |
| Two authors | 11 | 9.7 | 13 | 11.7 | 28 | 26.6 | 17 | 22.6 | 13 | 20.3 |
| Three authors | 13 | 11.5 | 10 | 9.0 | 18 | 17.1 | 13 | 17.3 | 15 | 23.4 |
| four authors | 7 | 6.1 | 12 | 10.8 | 13 | 12.3 | 13 | 17.3 | 12 | 18.7 |
| More than four authors | 77 | 68.1 | 75 | 67.5 | 42 | 40.0 | 31 | 41.3 | 23 | 35.9 |
| Total | 113 | | 111 | | 105 | | 75 | | 64 | |

Figure-2. Collaboration pattern of highly cited articles



5.4 Subject wise distribution of immensely cited articles

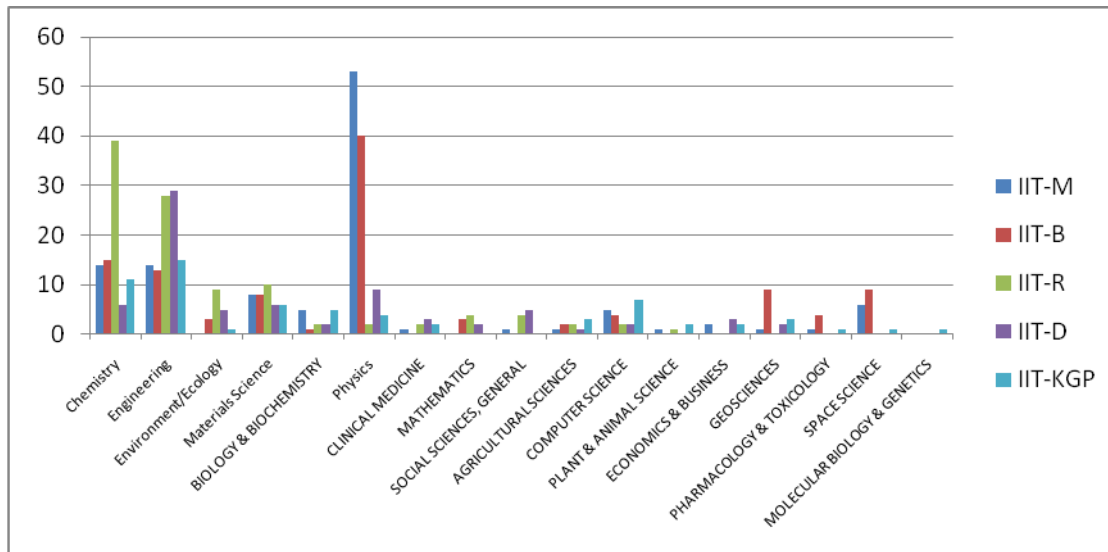
The broad subjects in which various selected IITs publish the immensely cited publications have been depicted in table4. In IIT-M 53 (46.9%) articles are greatly cited in Physics followed by Chemistry and Engineering with 14 (12.3%) articles each and a smaller amount of citations are received in Clinical Medicine, Social Sciences, Agricultural Sciences, Plant & Animal Science, Geosciences and Pharmacology & Toxicology. IIT-B, too has received enormous citations in Physics with 40 (36.0%) articles and a lesser amount in Environment/Ecology with 3 (2.7%) articles. IIT-R, IIT-D and IIT-KGP 28 (26.6%), 29(38.6%), and 15(23.4) articles have received immense citations in the Engineering, respectively.

Table-4. Subject –wise distribution

| Broad Subjects | No. of articles | | | | | | | | | |
|------------------------|-----------------|------|-------|------|-------|------|-------|------|---------|------|
| | IIT-M | % | IIT-B | % | IIT-R | % | IIT-D | % | IIT-KGP | % |
| Chemistry | 14 | 12.3 | 15 | 13.5 | 39 | 37.1 | 6 | 8.0 | 11 | 17.1 |
| Engineering | 14 | 12.3 | 13 | 11.7 | 28 | 26.6 | 29 | 38.6 | 15 | 23.4 |
| Environment/Ecology | 0 | 0 | 3 | 2.7 | 9 | 8.5 | 5 | 6.6 | 1 | 1.5 |
| Material Science | 8 | 7.0 | 8 | 7.2 | 10 | 9.5 | 6 | 8.0 | 6 | 9.3 |
| Biology & Biochemistry | 5 | 4.4 | 1 | 0.9 | 2 | 1.9 | 2 | 2.6 | 5 | 7.8 |
| Physics | 53 | 46.9 | 40 | 36.0 | 2 | 1.9 | 9 | 12.0 | 4 | 6.2 |
| Clinical Medicine | 1 | 0.8 | 0 | 0 | 2 | 1.9 | 3 | 4.0 | 2 | 3.1 |
| Mathematics | 0 | 0 | 3 | 2.7 | 4 | 3.8 | 2 | 2.6 | 0 | 0 |

| | | | | | | | | | | |
|------------------------------|-----|-----|-----|-----|-----|-----|----|-----|----|------|
| Social Sciences | 1 | 0.8 | 0 | 0 | 4 | 3.8 | 5 | 6.6 | 0 | 0 |
| Agricultural Sciences | 1 | 0.8 | 2 | 1.8 | 2 | 1.9 | 1 | 1.3 | 3 | 4.6 |
| Computer Science | 5 | 4.4 | 4 | 3.6 | 2 | 1.9 | 2 | 2.6 | 7 | 10.9 |
| Plant & Animal Science | 1 | 0.8 | 0 | 0 | 1 | 0.9 | 0 | 0 | 2 | 3.1 |
| Economics & Business | 2 | 1.7 | 0 | 0 | 0 | 0 | 3 | 4.0 | 2 | 3.1 |
| Geosciences | 1 | 0.8 | 9 | 8.1 | 0 | 0 | 2 | 2.6 | 3 | 4.6 |
| Pharmacology & Toxicology | 1 | 0.8 | 4 | 3.6 | 0 | 0 | 0 | 0 | 1 | 1.5 |
| Space Science | 6 | 5.3 | 9 | 8.1 | 0 | 0 | 0 | 0 | 1 | 1.5 |
| Molecular Biology & Genetics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1.5 |
| Total | 113 | | 111 | | 105 | | 75 | | 64 | |

Figure-3. Subject- wise distribution



5.5 Top five journals published highly cited publications

Table 5 portrays the top five journals that have published the highly cited articles by various IITs. IIT-M and IIT-B has published 11 and 12 articles respectively in Physical Review Letters, which are immensely cited. IIT-R has published 9 articles in the Journal of Colloid and Interface Science followed by 9 and 3 articles from IIT-D and IIT-KGP, respectively, in Renewable & Sustainable Energy Reviews. It is evident from the table that different IITs have selected different journals for publishing the research output and the preferred journals are Physical Review Letters, Physics Letters B, Renewable & Sustainable Energy Reviews, Physical Review D, Chemical Reviews, Journal of Materials Chemistry A and Nanoscale.

Table-5. Journal-wise distribution

| Name of the Journals | No. of articles | | | | |
|---|-----------------|-------|-------|-------|---------|
| | IIT-M | IIT-B | IIT-R | IIT-D | IIT-KGP |
| Physical Review Letters | 11 | 12 | 0 | 2 | 1 |
| Physics Letters B | 11 | 4 | 0 | 0 | 0 |
| Journal Of Colloid And Interface Science | 0 | 0 | 9 | 0 | 0 |
| Renewable & Sustainable Energy Reviews | 3 | 1 | 6 | 9 | 3 |
| Physical Review D | 8 | 2 | 0 | 1 | 0 |
| Journal Of Molecular Liquids | 0 | 0 | 7 | 0 | 0 |
| Journal Of High Energy Physics | 5 | 1 | 0 | 0 | 0 |
| Science | 2 | 4 | 0 | 1 | 0 |
| Astrophysical Journal Letters | 4 | 4 | 0 | 0 | 0 |
| Chemical Reviews | 2 | 4 | 0 | 1 | 1 |
| RSC Advances | 0 | 1 | 5 | 0 | 0 |
| Sensors And Actuators B-Chemical | 0 | 0 | 4 | 0 | 0 |
| Lancet | 0 | 0 | 2 | 3 | 0 |
| Journal Of Environmental Management | 0 | 0 | 0 | 3 | 1 |
| International Journal Of Information Management | | 0 | 0 | 3 | 0 |
| Chemical Engineering Journal | 1 | 0 | 5 | 0 | 3 |
| Journal Of Materials Chemistry A | 1 | 1 | 1 | 1 | 3 |
| Nanoscale | 2 | 2 | 0 | 2 | 3 |
| Progress In Polymer Science | 0 | 0 | 0 | 0 | 3 |

5.6 Top highly cited articles

Table 6 reveals the articles that are enormously cited and published in various journals by different selected IITs. The few articles which are cited above 800 times are displayed in the below-mentioned table. The article “Guidelines for the Use and Interpretation of Assays for Monitoring Autophagy” published in Autophagy is cited 2385 times, which is the highest citations among all the chosen articles, and IIT-KGP produces the research. “GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral” article published in Physical Review Letters has been cited 2278 times, which is collaboratively published by IIT-M & IIT-B. Journal of Geophysical Research-Atmospheres published “Bounding the Role of Black

Carbon in the Climate System: A Scientific Assessment” article, which is cited 2096 times, and the research output belongs to IIT-B. It is evident from the table that the top 6 articles mentioned in the below table are immensely cited as the citation range varies from 2385-1161 citations. The remaining five articles falls within the citation range of 838-807

Table-6. Top highly cited articles

| Articles | Source | Times Cited | Institution |
|--|--|-------------|---------------|
| Guidelines for the use and Interpretation of Assays for Monitoring Autophagy | Autophagy | 2385 | IIT-KGP |
| Gw170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral | Physical Review Letters | 2278 | IIT-M & IIT-B |
| Bounding the role of Black Carbon in the Climate System: A Scientific Assessment | Journal of Geophysical Research- Atmospheres | 2096 | IIT-B |
| Electrospinning: A Fascinating Fiber Fabrication Technique | Biotechnology Advances | 1864 | IIT-KGP |
| Hydrodynamics of Soft Active Matter | Reviews of Modern Physics | 1330 | IIT-M |
| Production of First and Second Generation Biofuels: A Comprehensive Review | Renewable & Sustainable Energy Reviews | 1161 | IIT-D |
| Simple One-Step Synthesis of highly Luminescent Carbon dots from Orange Juice: Application as excellent Bio-Imaging agents | Chemical Communications | 838 | IIT-KGP |
| Gravitational Waves And Gamma-Rays From A Binary Neutron Star Merger: Gw170817 And Grb 170817a | Astrophysical Journal Letters | 836 | IIT-M & IIT-B |
| Role Of Renewable Energy Sources In Environmental Protection: A Review | Renewable & Sustainable Energy Reviews | 828 | IIT-D |
| Gw170814: A Three-Detector Observation Of Gravitational Waves From A Binary Black Hole Coalescence | Physical Review Letters | 809 | IIT-M & IIT-B |
| Chemical Treatment Technologies For Waste-Water Recycling-An Overview | RSC Advances | 807 | IIT-R |

6. Findings

The important inferences drawn from the study are:

- i. A total of 468 highly cited articles have been published by five selected IITs in various areas during the period of the study i.e. 2010-2020. The maximum publications are

produced by IIT-M with 113 (23.15%) articles followed by IIT-B with 111 (23.71%) research publications and the minimum by IIT-KGP with 64(13.67%) articles.

- ii. In IIT-M and IIT-B a large number of highly cited research publications are published during the year 2017-2019 but in IIT-R, IIT-D and IIT-KGP the trend is arbitrary.
- iii. The collaborative model of more than four authors is preferred by the authors.
- iv. Physics, Chemistry and Engineering are the subjects in which maximum numbers of articles are published.
- v. Physical Review Letters journal has published the articles from all the five IITs in which enormous citations are received.
- vi. “Guidelines for the use and Interpretation of Assays for Monitoring Autophagy” received highest citations with 2385 citations published by IIT-KGP followed by “Gw170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral” received 2278 citations which is a collaborative effort by IIT-M & IIT-B.

7. Conclusion

The highly cited articles enhance the visibility of authors and an organization. They are considered as the influential research output in various disciplines. Various efforts at the national level to enhance the organizational output in the context of research and innovation to establish at world platform have been tremendously input into higher education, especially the technological education sector. The individual and collaborative research efforts are recognized through the citations and proliferation of cited research. Such observations reflect the measurements of institutional research visibility, impact, and specific contribution in the ranking system across the globe, beyond the national mirror of technological education. The bibliometric study of highly cited articles provides an overview of the quality research produced by the IITs in different fields. The impact of such hugely cited articles in building further research is noteworthy to the society and nation as a whole. The study is beneficial to researchers, academicians, funding agencies and administrators.

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