

The h-Index: Understanding its predictors, significance, and criticism

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ABSTRACT

The h-index is an author-level scientometric index used to gauge the significance of a researcher's work. The index is determined by taking the number of publications and the number of times these publications have been cited by others. Although it is widely used in academia, many authors find its calculation confusing. There are websites such as Google Scholar, Scopus, Web of Science (WOS), and Vidwan that provide the h-index of an author. As this metrics is frequently used by recruiting agency and grant approving authority to see the output of researchers, the authors need to know in-depth about it. In this article, we describe both the manual calculation method of the h-index and the details of websites that provide an automated calculation. We discuss the advantages and disadvantages of the h-index and the factors that determine the h-index of an author. Overall, this article serves as a comprehensive guide for novice authors seeking to understand the h-index and its significance in academia.

Keywords: Citations, h-index, impact, limitations, publications, scientometric index

Introduction

The h-index is a commonly used metric to measure the productivity and impact of academic researchers. It was first introduced in 2005, and since then, the h-index has become an important tool for evaluating researchers, departments, and institutions.^[1] The calculation of the h-index is relatively simple, yet it confuses novice authors. There are several websites where researchers can find their h-index autocalculated. While the h-index has several advantages, such as providing a simple and objective measure of a researcher's impact, there are also some limitations to its use. For example, the h-index does not take into account the quality of the publications or the context in which they were cited.^[2]

In this study, we will explore the calculation of the h-index, the websites where it is available, and the advantages and disadvantages of using this metric, and its predictors that increase the h-index of an author. By examining the strengths and weaknesses of the h-index, we hope to provide a comprehensive understanding of this important tool for evaluating scientific impact.

Calculation Method

The h-index is defined as the "highest number h, such that the individual has published h papers that have each been cited at least h times."^[3] For example, if an author has 10 papers and seven of those have been cited at least seven times each, then the h-index for that individual is 7. To make it more easy, we are presenting an example of how an author can calculate the h-index manually [Table 1]. To calculate the h-index, we first sort the papers in descending order based on their citation counts. Then, we count the number of papers that have at least as many

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citations as their position in the list. The table footnote describes situations where the h-index would be 8 or 9 in future.

Where to Get h-Index?

There are databases that provide the h-index information for authors for free. Some of the most commonly used websites that calculate the h-index of an author are listed as follows. The website titles, links, and services that are freely available are shown in Table 2.

Google Scholar

Perhaps it is the most commonly used website by scholars around the world. Google Scholar provides h-index information for authors based on the citations of their papers as indexed by Google Scholar.^[4] It is a free service provided by Google Scholar, and any researcher can open an account. However, if the researcher has an institutional email address, then the account can be made public after verifying the email. The authors can observe the year-wise citation count for a quick idea about the trend of citations over the years. An example is shown in Figure 1a.

Scopus

This database, provided by Elsevier, is another popular citation database that provides h-index information and other metrics, such as total citations and year-wise citations.^[5] Researchers can search for any name from the home page by clicking on “View your author profile” and searching by surname and name. However, we suggest creating a free account to track your own

articles and citations. An example is shown in Figure 1b. From the same homepage, the authors can also check the articles published and citation count of any journal by clicking on “View journal rankings.”

Web of Science

This database is maintained by Clarivate, and it is one of the most widely used citation databases. Previously, Researcher ID was provided by Thomson Reuters.^[6] Now, the Researcher ID is provided by Web of Science (WOS) that is maintained by the parent company Clarivate. The creation of an account is free in WOS. After creating the account, an author can view own details and also search for other researchers in the database. In the profile, WOS provides h-index information and other metrics, such as total citations, number of WOS-indexed articles, and number of citing articles. An example is shown in Figure 1c.

ResearchGate

This social networking site for researchers provides h-index information and other metrics, such as total citations and year-wise citations. To get the h-index in ResearchGate, one needs to create an account.^[7] Only published authors or invitee can create an account. Although ResearchGate suggests using the institutional email address, without it authors can open an account too. The authors need to send proof of publication for the creation of an account by a noninstitutional email address. In addition, those who are already in ResearchGate can send invitation to others to open an account. After logging in, the h-index is shown along with other metrics as shown in Figure 1d.

Vidwan

The Vidwan Expert Database and National Researcher's Network is a comprehensive platform designed to connect and showcase the expertise of scholars and researchers across various fields. It is a service provided by the Information and Communications Technology of Ministry of Education, India. The database is developed and maintained by the Information and Library Network Centre (INFLIBNET). This service is not open to all authors. Any recipient of national or internal award, any postgraduate with 10 years of professional experience, postdoctoral fellow, research scholar, professor (full, associate, or assistant), senior scientist, or having equivalent reaching or research post can open an account. This website shows the h-index along with total articles, year-wise articles, type of publication, total citations, citations available from

Table 1: h-index of an author who has 10 papers

Before arrangement		After arrangement	
Papers	Citation	Paper number	Citation
Paper A	10	Paper 1	34
Paper B	20	Paper 2	20
Paper C	12	Paper 3	18
Paper D	18	Paper 4	15
Paper E	2	Paper 5	12
Paper F	15	Paper 6	10
Paper G	5	Paper 7*	8
Paper H	8	Paper 8	5
Paper I	34	Paper 9	4
Paper J	4	Paper 10	2

The h-index of the author is 7. A total of seven of the papers got at least seven citations each. Eight of the papers have not received at least eight citations. The author's h-index will be 8 when “Paper 8” gets additional three or more than three citations. The author's h-index will be 9 when “Paper 7” gets additional one or more than one, “Paper 8” gets additional four or more than four, and “Paper 9” gets additional five or more than five citations

Table 2: Websites that calculate the h-index of an author

Title	Website	Information freely available
Google Scholar	https://scholar.google.com	Total articles, total citations, h-index, i10-index
Scopus	https://www.scopus.com	Total articles, total citations, year-wise publication and citations, h-index
Web of Science	https://www.webofscience.com	Total articles, WOS-indexed article, total citations, number of citing articles, h-index
ResearchGate	https://www.researchgate.net	Total articles, total citations, year-wise citations, number of citing articles, h-index
Vidwan	https://vidwan.inflibnet.ac.in	Total article, year-wise articles, type of publication, total citations, citations available from Crossref, number of coauthors, coauthor network, Altmetric scores, h-index

WOS: Web of Science



Figure 1: Examples of h-index of an author found in (a) Google Scholar, (b) Scopus, (c) Web of Science, and (d) ResearchGate showing discordance in h-index

Crossref (<https://www.crossref.org>), number of coauthors, coauthor network, and Altmetric (<https://www.altmetric.com>) scores. A part of the Vidwan profile with the h-index of a researcher is shown in Figure 2.

Why h-Index Differ?

The h-index can differ between different sites. One can see her/his h-index higher in Google Scholar than in Scopus or WOS.^[8]

Different databases may have different coverage and indexing policies. Some databases may include more or fewer journals, conference proceedings, or other sources of academic literature. This can affect the number of citations that are included in the h-index calculation.

Different databases may have different time lags in their citation data, meaning that citations may not be indexed at the same time or may be indexed differently based on the date of publication. This can affect the h-index calculation for a temporary period, especially if a researcher has recently published a highly cited paper that has not yet been indexed by a particular database.

In addition to the above factors, there may be errors or inconsistencies in the citation data used to calculate the h-index, which can lead to differences in the resulting h-index across different databases.

Therefore, it is important to use multiple sources of h-index information and to be aware of the potential differences between different sites. Google Scholar uses maximum sources to calculate the h-index. Hence, the h-index in Google Scholar may be the highest among the h-index provided by other databases. One question may still ponder: Which to take as the final h-index of an author? Although there is no simple answer to this question, Google Scholar may be considered the provider of the most comprehensive h-index. The impact of research is now not limited to citation in a journal article indexed by a single bibliographic database.

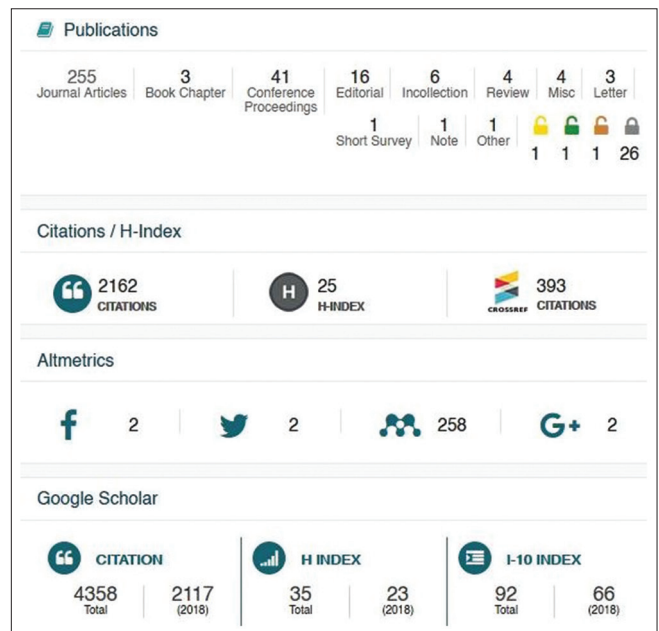


Figure 2: A part of a Vidwan profile showing the h-index and other metrics of the second author

Advantages of h-Index

The h-index has several advantages as a measure of research productivity and impact. The h-index takes into account both the number of publications and the number of citations those publications have received. This helps to balance the impact of quantity (by number of publications) and quality of publications (by number of citations it received) on the researcher’s overall research output. The h-index can be easily calculated using citation databases, such as Google Scholar. Being a free service, any author can get the h-index automatically calculated in Google Scholar. Scopus and WOS also provide their services free of charge for getting the h-index. We can use the h-index to compare the productivity and impact of researchers across different disciplines. The h-index is less affected by outliers. The h-index is less sensitive to individual highly cited papers or lowly cited papers, as it considers the total number of papers a researcher has published that have been cited a certain

number of times. It provides a long-term measure of research impact, as it takes into account the entire career of the researcher rather than just a single paper or a recent burst of activity.^[9]

Limitation of h-Index

Despite these advantages, the h-index is not without limitations. The h-index is criticized for favoring researchers who have been in the field for a longer period of time, as they have had more time to publish and accumulate citations. This can disadvantage early-career researchers. The h-index does not account for differences in citation practices between different fields or subfields, which can lead to unfair comparisons between researchers in different areas. The h-index relies on citation databases, which may not include all relevant citations. This can result in an inaccurate representation of a researcher's impact. However, this is common for all online calculated indices. The h-index includes citations to a researcher's own work, which can inflate the researcher's impact and may not accurately reflect their influence on the field. The h-index can be manipulated by self-citing excessively to increase the number of citations. The h-index does not take into account other important factors, such as the quality of publications, the impact of a researcher's work beyond citations, or their contributions to teaching and service.^[10]

Hence, the h-index should be used in conjunction with other metrics and qualitative evaluations to get a comprehensive assessment of a researcher's productivity and impact.

Usage of h-Index in Academia

There is no thumb rule of the level of h-index for hiring professionals or promotion of faculties. However, this index can be used by the universities for comparison of impact among the candidates for hiring or promotion. In addition, universities are commonly interested in recruiting a researcher with higher publication impact as the impact would be a feather to the crown of the university. A study by Wang *et al.*^[11] in the Department of Surgery, University of Alabama at Birmingham, Birmingham, Alabama, United States, found that a faculty has a median h-index of 6 at hiring, 11 during the promotion from assistant to associate professor, and 17 during the promotion from associate to full professor. In addition, Schreiber and Giustini studied 14 disciplines in North American medical schools and found that assistant professors have an h-index of 2 to 5, associate professors have 6 to 10, and full professors have an index of 12 to 24.^[12] A study by Kaur from India showed that top publishing authors in the medical field from All India Institute of Medical Sciences, Delhi, and Postgraduate Institute of Medical Education and Research, Chandigarh, have the h-index of 15 and 21, respectively.^[13] Nowak *et al.*^[14] analyzed 13 medical specialties and found that the median h-index was 19.5. There is a need for further research and reviews to get a generalizable result. Till we get that, the rule is "the more the merrier!"

Other Numbers and Indices Used in Academia

There are other author-level metrics that are used by various universities to evaluate research productivity and impact.

Some universities still use the total number of publications as a criterion for promotion. In addition, the total number of citations is also considered an indicator of research impact. This metric counts the total number of times an author's papers have been cited, regardless of the number of papers they have published. Furthermore, the average number of citations per paper for an author, which can provide insight into the overall quality and impact of their work, is sometimes considered. Table 3 shows the various other calculations and indices that are used.

The i10-index is another simple measure that indicates the number of papers that have received 10 citations each. It is shown in a Google Scholar profile along with the h-index of an author [Figure 1a].

The g-index is another metric that is not readily found calculated in the above database websites, but one can manually calculate the g-index of an author. It gives more weight to highly cited papers. It is calculated by finding the largest number of g such that the top g papers have a total of at least g^2 citations. For example, in Table 1, the author had a g-index of 10 as cumulative citations on the 10th paper are more than 10^2 [Table 2]. If the author had a 11th paper with even 0 citations, the g-index would be 11 (as cumulative citations are more than 11^2). However, if the author had a 12th paper with 0 citations, the g-index could be 11 as cumulative citations were below 12^2 .^[3]

The m-index is a metric that takes into account the h-index and years of activity of an author.^[15] Its calculation is simple. For example, if the author is publishing the papers shown in Table 1 for the last 5 years, the m-value or m-index would be 1.4 (7/5) [Table 3].

It is important to note that no single metric can provide a comprehensive evaluation of a researcher's productivity and impact, and these metrics should be used in combination with other qualitative evaluations. Furthermore, no index is still there in academia that is capable of judging the quality of a research paper.

Table 3: Other calculations and indices (calculated from data in Table 1)

Metric	Value
Total articles	10
Total citations	128
Average citation	12.8
i10-index	6
g-index	10
m-value	1.4

Factors that Influence h-Index

Achieving a high h-index can be a long-term process that requires sustained research productivity and impact.^[16] Here are some factors that have the potential to influence the h-index.

Publish in high-impact journals

Publishing in high-impact journals can help to increase the visibility and impact of one's research, leading to more citations and a higher h-index. High-impact journals are typically those with a large readership and reputation for publishing groundbreaking research. Articles published in these journals tend to be highly cited and can have a significant impact on their respective fields.^[17]

Make research openly accessible

Making research freely and openly accessible can increase the visibility and impact of one's work, leading to more citations and a higher h-index. Open-access articles can reach a wider audience and potential readership, including researchers who might not have access to the article through traditional subscription-based methods. Additionally, open-access articles can be easily shared on social media platforms, blogs, and other online forums, which can increase their reach and promote their visibility.^[18]

Collaborate with other researchers

Collaborating with other researchers can lead to more publications and citations, as well as exposure to new research ideas and methods. Collaboration can bring together researchers with different areas of expertise and skill sets, resulting in more comprehensive and impactful research. Collaborating with other researchers can increase the visibility of the research. Collaborators are likely to share the research with their networks, potentially increasing the readership and citations of the work.^[19]

Balance quality and quantity

While the quantity of publications is important, it is more important to focus on producing high-quality research that is impactful and well-regarded in the field. Higher-quality articles are more likely to be cited by other researchers, which can further increase their impact and visibility.^[20] However, the number is also important. For example, if an author has five papers with a huge 50000 citations, the h-index would be 5 only.

Stay active in the field

Attending conferences can provide opportunities to meet other researchers and learn about new research in the field. By presenting one's own research at a conference, researchers can receive feedback and ideas from other scholars, which can lead to new collaborations and research opportunities. Attending conferences also provides opportunities to network with other researchers. Delivering talks or lectures can also increase visibility and impact. Participating in scholarly discussions, such as by commenting on blogs or participating in online forums, can

also increase visibility, which increases the chances of higher citations.^[21]

Promote your research

Promoting research can be an effective strategy for increasing citations. There are several ways to promote research, including sharing it on social media, collaborating with other researchers, and seeking media coverage. Sharing research on social media can be an effective way to increase visibility and reach a wider audience. Researchers can share their work on their personal or professional social media accounts or on specialized platforms, such as ResearchGate or Academia.edu.^[22] Seeking media coverage can also be an effective way to promote research and increase citations. Media coverage can increase the visibility of the research and attract the attention of other researchers who may be interested in citing the work. Researchers can also promote the articles on their own websites for a higher reach in the field, which lead to more citations and a higher h-index.^[21]

Conduct timely research

By working on influential research and trending topics, researchers can increase the likelihood that their work will be cited by other researchers in the field. To conduct timely research, researchers need to stay up-to-date on the latest developments and emerging trends in their field. This may involve reading relevant literature, attending conferences, and collaborating with other researchers. By staying current with the latest research, researchers can identify gaps in the field and opportunities for making meaningful contributions.^[23]

It is important to note that these strategies should not be used to game the system or artificially inflate one's h-index, but rather as ways to increase the impact and visibility of one's research in a genuine and sustainable way.

Institutional Level Data

The institutional h-index is not readily available in Google Scholar. However, one can manually search the total publications from the institution and citation to the published article from the institutional repository (if available) to calculate the h-index of the institution. The calculation method remains the same. Institutions that do not have their own repository can collect data from Google Scholar about publications and citations. If the institution provides an email address to the employee, and teachers or researchers verify the email address, the data can be collected from Google Scholar from the following method. The website https://scholar.google.com/citations?mauthors=aiimsdeoghar.edu.in&hl=en&view_op=search_authors is opened if the institution has the Uniform Resource Locator (URL) as aiimsdeoghar.edu.in. All the authors who verified their accounts would be shown with their papers and citations.^[24] These data can be used to calculate the central tendencies of the h-index of the authors in that institution. A similar method can be used to extract data from other databases, such as Scopus, to compute

the institution-level h-index.^[25] Institutions may also open a user account as a researcher in Google Scholar as shown in Figure 3 and add the published “Add article manually” (after clicking the addition “+” button) to get institutional level h-index.

The h-index of global institutions can also be found at <https://exaly.com/institutions/citations>. This website hosts data of 53,307 institutions along with their h-index. Exaly is a nonprofit initiative aimed at filling the gap of lacking an inclusive and accessible collection of academic papers and scientometric information. It is referred to as a project rather than an organization to ensure independence from commercial motives. Indian regional data are available on a website https://www.indianscience.net/list_inst.php that provides data till 2019. This website extracted data from Dimensions (<https://www.dimensions.ai>) and Altmetric (<https://www.altmetric.com>).^[26]

Conclusion

In conclusion, the h-index is a widely used metric for measuring the productivity and impact of researchers. While it has some limitations, such as its inability to capture the quality of publications and the potential for manipulation, the h-index remains a useful tool for evaluating the performance of individual authors and comparing researchers and institutions. Hence, the potential predictors of the index were discussed along with its calculation methods. The h-index in conjunction with other metrics and factors for evaluating research productivity and impact was also highlighted.

Self-Assessment Multiple-Choice Questions

Five questions are available in Table 4 for self-assessment of your learning from this article.

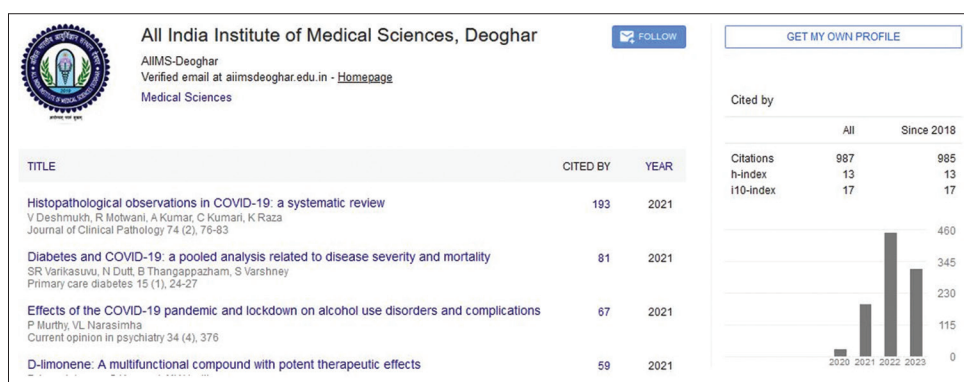


Figure 3: A profile of an institution in Google Scholar

Table 4: Self-assessment multiple-choice questions

Question number	Question	Response option
Q1	Where can an author get the h-index?	A) Google Scholar B) Scopus C) Web of Science D) All of the above
Q2	What we need to calculate the h-index?	A) Published articles B) Citations to the published articles C) Arrangement of articles according to citation in higher to lower order D) All of the above
Q3	An author has published five papers that have been cited as follows: 21, 12, 4, 2, and 1. What will be the h-index of the author?	A) 5 B) 8 C) 3 D) 2
Q4	An author has published 10 papers that have been cited as follows: 9, 7, 3, 11, 4, 8, 2, 12, 6, and 1. What will be the h-index of the author?	A) 5 B) 6 C) 2 D) 4
Q5	What is false about the h-index?	A) Different databases may show different h-index of an author B) ResearchGate profile shows the h-index of an author C) Self-citations can increase the h-index D) h-index calculation needs the years of activity of an author

Answers

Q1: The correct answer is D. Google Scholar, Scopus, and Web of Science show the h-index of an author

Q2: The correct answer is D. We need the total papers and their citations to be arranged in higher to lower order for ease of identification of the h-index.

Q3: The correct answer is C. Three papers of the author have received at least three citations each.

Q4: The correct answer is B. Six papers of the author have received at least six citations each.

Q5: The correct answer is D. The h-index only takes papers and their citations. m-value considers the years of activity of an author

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Conflicts of interest

There are no conflicts of interest.

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