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Research Practices and Priorities of Chemistry Researchers in the Western Himalayan Region of India

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ABSTRACT

The study aims to visualise the citation behaviour of Chemistry researchers in the Western Himalayan Region of India by analysing 16,823 sources cited in Scopus-indexed publications from 2012 to 2021. Employing the Bibliometrix and Biblioshiny packages within R Studio, the research delves into various bibliometric variables and keywords to present a detailed picture of Chemistry research. The study revealed significant insights into how Chemistry researchers in this region engage with the literature, predominantly relying on high-impact journal articles and reviews, with lesser emphasis on other document types. The visual analysis, including keyword occurrences and co-word network mappings, highlights prominent research themes such as 'material synthesis and applications' and 'chemical and biological functions'. Additionally, visual tools like word clouds and tree-maps demonstrate the frequency and distribution of these keywords, emphasising the importance of interdisciplinary research that bridges Chemistry with fields like Biology, Materials Science, and Technology. The findings provide crucial information for stakeholders such as researchers, policymakers, and funding bodies, enabling them to grasp the research dynamics and priorities in the region.

Keywords: Citation behaviour; Citation analysis; Central universities; Western Himalayan region; Chemistry; Biblioshiny

1. INTRODUCTION

The Himalayas, which translates to "*Adobe of Snow*" in Sanskrit, is a beautiful mountain range that crosses eight South Asian nations. The Himalayas are a series of mountains that rise more than 7,000 meters above sea level and stretch an average of 2,500 kilometers in length and 300 kilometers in breadth along the northern edge of the Indian subcontinent[1-2]. The Western Himalayan, Central Himalayan, and Eastern Himalayan Region comprise the three primary areas that make up the whole Himalayas[3]. India's The Western Himalayan Region (WHR) stands out as a distinct area, both physically and culturally, marked by wild natural scenery, extreme weather conditions, and a rich variety of biological species. The region is known for its unique geology, with deep forests, high deserts, and alluvial plains home to various animal species[4-6]. The WHR is the most significant part of the Indian Himalayas. It is home to many research and higher education institutions that are crucial for promoting research and education in various sectors. The WHR consists of Jammu, Kashmir, Himachal Pradesh, and Uttarakhand[3]. The scope of this study is limited to the Central University of Himachal Pradesh (CUHP), Central University of Jammu (CUJ), Central University of Kashmir (CUK), and Hemwati Nandan Bahuguna Garhwal University (HNBGU), all located within this region. These universities offer a wide array of undergraduate, graduate, and doctoral programs and engage in research across diverse disciplines.

The list of cited sources or references is considered a critical resource for the academic community to access research related to their study. There is a plethora of reasons why references are used. Many researchers have attempted to investigate the reasons for citations; Garfield[7] discussed potential motivations for authors citing other publications. The study of citation behaviour involves assessing and examining the cited sources, which appear at the end of the scientific communication. Smith[8] suggests that analysing reference lists can be an effective way to test hypotheses about information usage or to compare current user behaviour with that of past years. He notes that while citations don't exactly mirror usage, they do provide insights into the behaviours associated with scientific research, particularly in terms of how researchers choose their references based on specific motives[9]. Tracking citations, therefore, not only helps in understanding the dissemination of knowledge but also in evaluating the influence of scientific work.

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Depending on the information types analysed, several analytic techniques are employed in bibliometrics. The most typical ones are co-authorship analysis, co-word analysis, or keyword co-occurrence analysis based on citations[10-12]. Citation analysis is a recognised approach for determining the impact and relevance of research within various fields[13]. This method, increasingly important for assessing the research environment in developing countries like India, involves studying the references in research publications to identify patterns in scholarly communication, as explained by Reitz[14]. Historically, citation analysis has been employed to examine the reasons behind citation practices and to assess the impact of scientific work. As discussed by Garfield[7] and others, motivations behind citations can vary, including validating data, aligning with community standards, or acknowledging prior influences.

Recent studies like that of Muruli and Harinarayana[36] (2024) on Physics and Astronomy researchers have shown a preference for citing significant journal articles and reviews, with a noticeable trend towards co-authorship among smaller collaborative groups. Drawing from these insights, the present study employs a bibliometric approach to investigate the citation patterns among chemistry researchers in the Western Himalayan Region. By analysing how these researchers engage with existing literature and how their citation behaviours mirror wider academic trends, this study aims to offer a comprehensive view of scholarly communication within the field of chemistry in the Western Himalayas. This research is crucial for stakeholders such as academic institutions, policymakers, and scholars who rely on such analyses to formulate strategies for future research directions, enhance educational practices, and boost the overall impact of scientific research in regions like India.

2. LITERATURE REVIEW

Numerous studies have explored the influence of citation behaviour on the flow of information and the structure of intellectual domains. According to Yang and Liu[9], how sources are cited significantly affects the spread of knowledge and the configuration of intellectual frameworks. Cui[31] and colleagues investigated how researchers often cite prominent works and are influenced by their professional networks. This kind of analysis highlights specific behavioural patterns in the data, making it a valuable tool for enhancing the understanding of scientific communication processes. The most apparent manifestation of a researcher's citation habits appears in the references of their publications[32].

A thorough evaluation of these sources also referred to as citation analysis, was emphasised by Liang and Rousseau[33] as a crucial metric for assessing research impact over mere citation counts. They argued that analysis should focus more on the references cited in papers. Bornmann and Daniel[15] conducted a comprehensive review of existing research on how citation behaviour and frequency contribute to assessing scientific influence. Citation analysis is now a crucial tool for librarians, information specialists, and academic researchers. Tavernaro and Salisbury[16], along with Atkinson and Thornton[17], emphasised the advantages of using citation analysis to understand scholarly communication and manage library collections effectively.

Research evaluating the citation behaviour of various academic communities has been conducted. Kodandarama and Chandrashekara[18-19] examined the references used by faculty members and researchers at the two state universities of Karnataka. At the same time, Kimball[20] and his team studied the citation practices of the Atmospheric Science researchers at Texas A & M University. The citation behaviours of diverse groups, including faculty, research scholars, and students, have also been analysed. In 2006, Carlson[21] examined the citation behaviour of undergraduate students, and Clarke and Oppenheim[22] studied the citation practices within the information science department at Loughborough University. Bhat and Sampath Kumar[23] focused on web references in academic e-journals. Hakak and Ali[24] conducted a citation analysis of articles from the *'Annals of Library and Information Science'* spanning 2010 to 2019. Singson[25] and colleagues explored the citation practices of faculty at Pondicherry University, while other studies[26-30] have conducted bibliometric analysis specifically in the field of chemistry.

3. OBJECTIVES OF THE STUDY

This study aims to analyse the 'citation behaviour' of Chemistry researchers in the WHR of India with the following specific objectives:

- Identify Predominant Document Types: Determine which types of documents are most commonly cited by researchers.
- Assess Reliance on Peer-Reviewed Articles: Evaluate the extent to which researchers rely on peer-reviewed articles as their primary information source.
- Create a Word Cloud of Author Keywords: Generate a word cloud to visualise the most prevalent author keywords in the cited literature, highlighting core research themes.
- Develop a Tree-Map of Title Keywords: Use a tree-map to display the most frequent title keywords, providing an overview of primary research topics.
- Conduct a Co-Word Network Analysis: Perform a co-word network analysis to visualise connections between keywords and reveal the interdisciplinary nature of chemistry research.

4. METHODOLOGY

The study explores the citation behaviour of chemistry researchers in the WHR of India by employing bibliometric analysis techniques such as co-word network analysis and visualisation tools like word cloud and tree-map visualisations. The methods utilised offer a novel approach to understanding research practices and priorities in a specific academic context.

4.1 Data Collection

The first step in conducting a bibliometric analysis of cited sources was to retrieve data from the scopus database. Scopus[34] is a well-known and comprehensive bibliographic database frequently used in academic research. This process involved querying the database using Scopus affiliation identifier*(CUHP-60107368; CUJ-60104778; CUK-60107398; HNBGU-60069550)*for universities in the Western Himalayan Region of India. Scopus uses unique identifiers (Scopus Affiliation Identifier) for each affiliation, allowing it to categorize documents linked to specific institutions distinctly. The search criteria were limited to research '*articles'* and '*reviews'* published by the Chemistry researchers within a specified timeframe (2012-2021). This search yielded a dataset of 16,823 references, keywords, and other bibliographical details. The retrieved data was exported into BibTeX and CSV file formats for further analysis.

4.2 Analysis of Data

The data analysis was performed using the well-known bibliometric analysis software packages Bibliometrix and biblioshinyof R Studio. Bibliometrix was used for descriptive statistics; examining aspects such as document types, frequently cited sources, authors, affiliations, and countries. Bibliometrix offers tools for importing bibliographic data from major databases like scopus, Clarivate Analytics' Web of Science, and PubMed. It supports the execution of bibliometric analyses and helps create data matrices for various bibliometric techniques such as co-citation analysis, coupling analysis, scientific collaboration analysis, and co-word analysis. Biblioshiny was used for co-citation, co-word network analysis and keyword mapping. It provides a user-friendly interface for bibliographic data analysis and visualisation. Both tools are open-source and provide robust capabilities for bibliographic data analysis.[35]

5. DATA ANALYSIS AND INTERPRETATION

5.1 Document Types

Interesting insights into the citation behaviour of chemistry researchers in the WHR of India are revealed by analysing the data on cited references. As shown in Table 1, articles account for 73.6 % of total citations, highlighting their significance as primary information sources. Researchers at selected universities heavily rely on articles for their research and scholarly contributions. Data emphasises the importance of utilising existing research in the region and remaining current on the most recent literature. The results show little emphasis is placed on citing books and book chapters, as their citation rates are pretty low (overall 0.29 % and 0.45 %). However, it is worth noting that books and book chapters can provide comprehensive knowledge and in-depth analyses. Reviews substantially influence the citation landscape, contributing to 10.55 % of total citations. Various other document types, such as conference papers, data papers, editorials, and others, collectively contribute to a smaller proportion of citations (ranging from 0.01 % to 1.87 %). Although their impact is lower, these document types can offer unique insights, discussions, and specific research findings. Overall, the analysis suggests that chemistry researchers in the WHR rely on articles and reviews as their primary reference source, and there is a low emphasis on citing other document types.

5.2 Most Frequently Cited Journals

Table 2 shows that the *Journal of the American Chemical Society* is the most cited in the field of chemistry, with 345 articles cited. This journal had a high h-index of 674, indicating a considerable number of highly cited articles. With a CiteScore of 25.2, it is considered a prominent and influential journal in this field. Its prominence at the top of the list demonstrates

Table 1. Types of documents cited by chemistry researchers of the Western Himalayan region of India

S. No.	Document types	CUHP	%	CUJ	%	CUK	%	HNBGU	%	Total	%
1	Article	2519	81.26	5836	75.72	580	74.07	3446	65.85	12381	73.6
2	Book	9	0.29	29	0.38	2	0.26	9	0.17	49	0.29
3	Book chapter	6	0.19	38	0.49	6	0.77	25	0.48	75	0.45
4	Conference paper	42	1.35	170	2.21	12	1.53	91	1.74	315	1.87
5	Data paper	0	0.00	1	0.01	0	0.00	0	0.00	1	0.01
6	Editorial	5	0.16	17	0.22	0	0.00	7	0.13	29	0.17
7	Erratum	2	0.06	0	0.00	0	0.00	1	0.02	3	0.02
8	Letter	8	0.26	10	0.13	1	0.13	21	0.40	40	0.24
9	Note	6	0.19	11	0.14	2	0.26	13	0.25	32	0.19
10	Retracted	0	0.00	1	0.01	0	0.00	0	0.00	1	0.01
11	Review	300	9.68	916	11.89	126	16.09	432	8.26	1774	10.55
12	Short survey	11	0.35	16	0.21	6	0.77	21	0.40	54	0.32
13	Undefined	192	6.19	662	8.59	48	6.13	1167	22.30	2069	12.3
Total		**3100**	**100**	**7707**	**100**	**783**	**100**	**5233**	**100**	**16823**	**100**

Table 2. Top ten journals cited by the chemistry researchers

S. No.	Sources	No of articles cited	Country	Publisher	h-index	SJR (2022)	Quartile (2022)	CiteScore (2021)
1	Journal of the American Chemical Society	345	USA	American Chemical Society	674	5.95	Q1	25.2
2	Organic Letters	231	USA	American Chemical Society	252	1.56	Q1	10.4
3	Angewandte Chemie–International Edition	212	UK	John Wiley and Sons Ltd	612	5.57	Q1	23.9
4	Journal of Organic Chemistry	203	USA	American Chemical Society	239	0.89	Q1	7.2
5	Chemical Reviews	201	USA	American Chemical Society	790	18.91	Q1	98.8
6	RSC Advances	186	UK	Royal Society of Chemistry	189	0.68	Q2	5.9
7	Chemical Communications	174	UK	Royal Society of Chemistry	363	1.34	Q1	10.2
8	Tetrahedron Letters	156	UK	Elsevier Ltd.	178	4.3	Q3	0.39
9	Chemical Society Reviews	155	UK	Royal Society of Chemistry	595	15.11	Q1	75.9
10	ACS Applied Materials and Interfaces	139	USA	American Chemical Society	284	2.18	Q1	14.4

Note: Metrics of h-index, SJR, and Quartile are based on the Scimago Journal & Country Rank, and the CiteScore data is based on Scopus (as of May 24, 2023)

its significance and widespread acceptance among researchers in chemistry. The list contains publications from various publishers, including Elsevier Ltd., the American Chemical Society, and the Royal Society of Chemistry. This diversity indicates the behaviour of citing or referring to a range of sources. *Angewandte Chemie - International Edition, Chemical Reviews*, and *Chemical Society Reviews* are among the list journals with high h-index values, indicating their significant impact and the number of articles with high citation counts. In addition, these journals have a high CiteScore, indicating their broad readership and influence among scientists. The fact that all ten of the top journals are published in the USA and the UK demonstrates the global nature of chemistry research, as well as solid research output and the influence of nations on research. The SJR and Quartile measurements show the significance and effect of journals in their fields. Journals with higher Quartile and SJR values were considered more prestigious and influential. Examining these measurements can assist scientists in evaluating the quality and impact of the journals to which they refer. Overall, Table 2 provides valuable information on the sources most frequently cited by WHR chemical researchers in India and their practice of citing high-impact peer-reviewed journals.

5.3 Top 50 Author Keywords

In a graphical display, Figure 1 showcases a word cloud depicting the top 50 author keywords from cited sources, with the most frequently occurring words appearing larger and in bold, highlighting their prominence. The word cloud highlights several prominent author keywords that reflect the critical areas of research interest within Chemistry. Some of the notable author keywords inc*lude "adsorption," "graphene," "nanoparticles," "palladium,"* and *"graphene oxide."* These keywords suggest that researchers in chemistry have been actively studying topics related to adsorption processes, the properties and applications of graphene and graphene oxide materials, and the synthesis and characterisation of nanoparticles. Other significant author keywords include *"heterocycles," "antioxidant," "fluoride," "synthesis,"* and *"kinetics."* These keywords point to areas of research focused on the study of heterocyclic compounds, the investigation of antioxidants and their activities, the behaviour and effects of fluoride, synthesis methodologies, and the kinetics of chemical reactions. Figure 2 also reveals author keywords related to specific applications and areas of study, such as *"drug delivery," "supercapacitor," "cancer," "photocatalysis,"* and *"antimicrobial activity."* These keywords indicate that researchers have been engaged in research involving drug delivery systems, energy storage devices like supercapacitors, cancer-related studies, photocatalytic processes, and investigations into antimicrobial properties.

5.4 Top 50 Title Keywords

Figure 2, on the other hand, presents a tree-map visualisation of the top 50 title keywords in the sources cited by Chemistry researchers. The size of each keyword in the tree map reflects its frequency of occurrence, providing an overview of the most commonly cited terms.

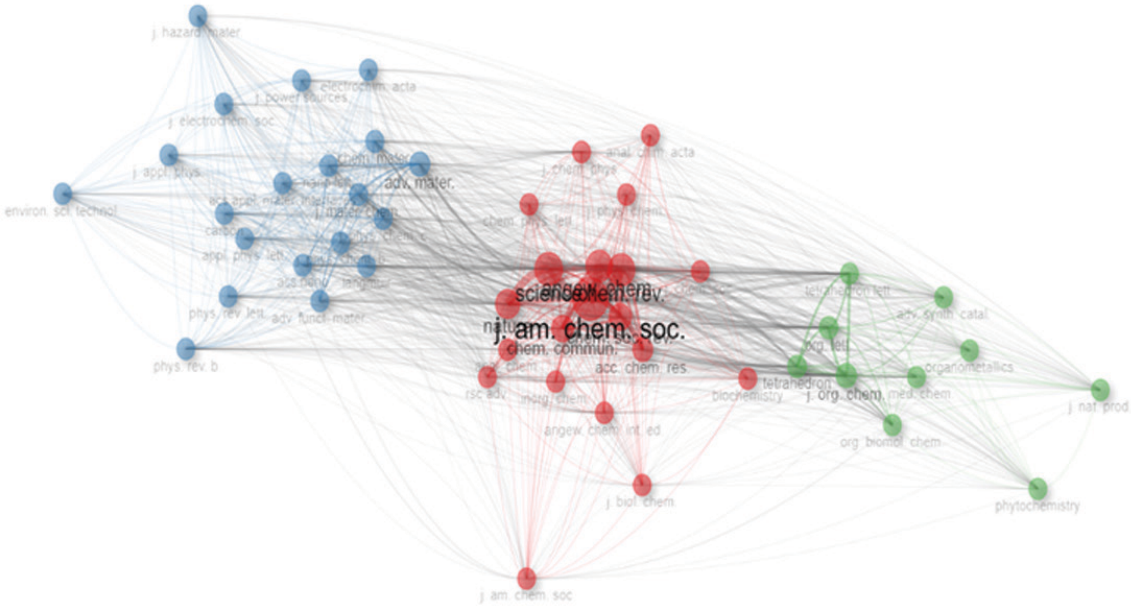

Figure 1. Co-citation network of sources.

Figure 2. World clouds of top 50 author keywords.

The tree map highlights the prevalence of keywords such as *"synthesis," "properties," "graphene," "nanoparticles,"* and *"carbon,"* indicating their significance in the titles of cited sources. Other important title keywords include *"activity," "oxide," "water," "reaction,"* and *"materials,"* suggesting the research focuses on chemical and biological activity, oxide materials, water-related phenomena, various reactions, and varied materials. The presence of keywords like *"acid," "organic," "metal,"* and *"molecular"* reflects the interest in acid-related studies, organic compounds, metal-based research, and molecular-level investigations. Furthermore, Figure 3 reveals keywords associated with specific applications and areas of study, such as *"films," "batteries," "cancer,"* and *"detection."* These keywords imply research interests in thin films, battery technologies, cancer-related studies, and detection methods.

5.5 Co-Word Network Analysis

Based on author keywords, the co-word network analysis shown in Figure 3 sheds light on the connections between various research topics. The network is made up of four important clusters, each of which represents a separate set of keywords that are frequently used in research articles together. Keywords like *"adsorption," "nanocomposite," "drug delivery,"* and *"photocatalysis"*

are included in Cluster 1. Keywords like *"synthesis," "essential oil," "fluorescence," and "cytotoxicity"* are included in Cluster 2. Keywords like *"graphene,"* nanoparticles, and carbon nanotubes are the focus of Cluster 3. Keywords in these clusters have solid associations and connections with one another, indicating a close connection in the research literature. In addition, the examination recognizes keywords inside each group with high betweenness centrality, recommending their primary job in associating different exploration points. Keywords like *"adsorption"* and *"nanocomposite,"* for instance, are essential in connecting the various research topics in Cluster 1. Similarly, the word *"synthesis"* serves as a guiding principle in Cluster 2, connecting various aspects of scientific investigation.

Keywords like *"graphene"* and *"graphene oxide"* are necessary connectors in Cluster 3, highlighting the significance of graphene-based applications-related materials and technologies. The co-word network examination empowers scientists to acquire a more profound comprehension of the connections and relative significance of various exploration subjects inside their fields. It assists in better navigating the research landscape, fostering interdisciplinary collaborations, and identifying emerging trends. Researchers can keep up with the ever-evolving scientific landscape by visualizing the connections and interdependencies between keywords. They can also discover potential areas for collaboration.

6. FINDINGS AND CONCLUSIONS

The tables and figures presented in this study provide valuable insights into the research landscape of Chemistry. The visual representations of keywords demonstrate a comprehensive overview of the prominent research topics, areas of study, and emerging trends within the field. The co-word network examination, as depicted in Figure 3, uncovers fascinating examples and relationships between various exploration points based on author keywords. The results of the co-word network analysis are further supported by the tree-map visualisation in Figure 2 and the word clouds in Figure 1. These visual representations depict the frequency and distribution of keywords found in the sources cited by Chemistry researchers. The word cloud reveals prominent author keywords like *"adsorption," "graphene,"* and *"nanoparticles,"* reflecting the interest in material properties and applications. The tree-map visualisation highlights the significance of keywords like *"synthesis," "properties,"* and *"graphene"* in the titles of the cited sources. The research topics and clusters reflect the diverse interests and changing trends in the field. Scientists have been effectively concentrating on research areas like 'material synthesis,' characterisation, and applications, with a particular spotlight on nanomaterials like 'graphene' and nanoparticles. Much attention has also been paid to studies of catalysis, drug delivery systems, and various chemical and biological activities. The results also show that interdisciplinary research is getting increasingly important, with chemistry collaborating with fields like biology, materials science, and technology.

It is essential to recognise that bibliometric analysis presents significant advantages in understanding research practices and priorities. However, we must also acknowledge its limitations, which include possible biases in the database coverage, the keywords authors select, and the interpretation of co-occurrence networks. Furthermore, it is important to note that the study's focus on a single region and a specific timeframe may limit the generalisability of the results. Overall, this study examined the citation behaviours of chemistry researchers at central universities in the Western Himalayan Region using bibliometric analysis.

The study aimed to understand how chemistry researchers cite sources and how the patterns of reference practices and distributions can support policymakers, funders, and other researchers. The study's findings

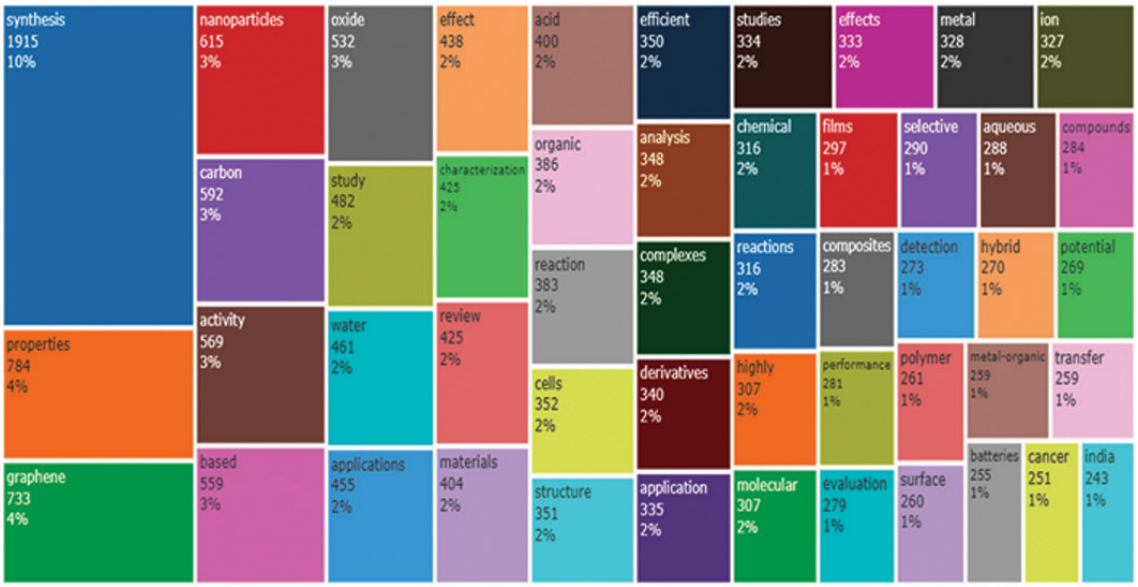

Figure 3. Tree-map visualization of top 50 title keywords.

provide insights into important research areas, study topics, and trends in chemistry. The co-word network analysis highlights the interconnectedness of different research topics. At the same time, the word clouds and tree-map visualisations provide a glimpse into the frequency and distribution of keywords within cited sources. These findings emphasizes the dynamic nature of chemistry research and emphasize the need for researchers to stay updated on emerging areas to contribute effectively to the field. This research helps to enhance our knowledge of citation behaviour and research practices used in chemistry research at the central universities in the western Himalayan region of India.

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