South African research contributions to *Lecture Notes in Computer Science*, 1973–2022

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DATES:
Received: 21 Nov. 2022
Revised: 06 Oct. 2023
Accepted: 01 Nov. 2023
Published: 30 Jan. 2024

HOW TO CITE:
Naudé F, Kroeze JH. South African research contributions to *Lecture Notes in Computer Science*, 1973–2022. S Afr J Sci. 2024;120(1/2), Art. #15199. https://doi.org/10.17159/sajs.2024/15199

ARTICLE INCLUDES:
☒ Peer review
☐ Supplementary material

DATA AVAILABILITY:
☒ Open data set
☐ All data included
☐ On request from author(s)
☐ Not available
☐ Not applicable

EDITORS:
Chrissie Boughey
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KEYWORDS:
authorship, bibliometrics, *Lecture Notes in Computer Science*, South Africa, computer science researchers

FUNDING:
South African National Research Foundation (grant no. 132180), University of South Africa

Lecture Notes in Computer Science (LNCS) is a globally recognised publication outlet for the field of Computer Science, including in South Africa. In this study, spanning from 1973 to 2022, we investigated the research participation of South African based authors in LNCS. The publication output and citation impact of these authors were compared to the global Computer Science and LNCS output. The authorship patterns and collaborative behaviour of South African LNCS papers were explored, and a keyword or topic analysis also conducted. Of the total of 518 662 LNCS papers published globally between 1973 and 2022, South African based researchers contributed 1150 papers (0.22%). The LNCS papers from South Africa exhibit a strong collaborative publication culture, with 1043 (91%) co-authored and 107 (9%) single-authored works. Local LNCS researchers prefer institutional collaboration (43%), followed by international (37%) and national collaboration (11%). Europe emerged as the most significant collaboration partner for LNCS researchers in South Africa. Of the 1150 papers, 836 (73%) had received citations, while 314 (27%) had not. On average, papers published by South African based authors received 6.05 citations, compared to the global LNCS average of 9.49 citations per paper. A keyword analysis revealed that the majority of papers by South African authors focus on artificial intelligence. The results indicate that, although LNCS serves as a reputable dissemination platform for Computer Science research output both globally and locally, South African authors should consider publishing more journal articles to build and improve their researcher profiles.

Significance:

- The study shows that LNCS is the most frequent publication outlet for Computer Science researchers, globally and in South Africa.
- The study offers insight into the publication output, authorship patterns, collaborative behaviour and citation impact of South African based Computer Science researchers.

Introduction

Lecture Notes in Computer Science (LNCS), a conference proceedings book and e-book series, is the most prevalent and prominent publication outlet for Computer Science globally[1] and in the Republic of South Africa[2,3]. The series is well established and highly respected. It was founded in 1973[4,5] and is published by Springer, the world's largest academic publisher[6]. Established in 1950, Springer is a reputable publisher of influential scholarly publications[7], which adds to the credibility of LNCS and makes it an attractive venue for researchers. In this article, the term 'Computer Science' is used as an umbrella term for the field encompassing all the sub-disciplines of Computer Science, Information Systems and Information and Communication Technology. This use of the term is in line with its use by Scopus and Springer. Some authors use the terms 'Computing' and 'Computer Sciences' as alternatives.

LNCS established itself as a primary dissemination channel for the publication of the latest developments in Computer Science research. The series includes the sub-series *Lecture Notes in Artificial Intelligence* and *Lecture Notes in Bioinformatics*, both of which were also included in the empirical work of this study. When LNCS commenced publication in 1973, it rapidly attracted attention because of its unprecedented publication turnaround times. In the late 1990s, Springer developed a systematic approach to publishing LNCS as a full-text electronic version in parallel to printed books. Original research results reported in pre-conference peer-reviewed proceedings and revised post-proceedings remain the core of LNCS.[4] The formats within its 2021 e-book collection underline the importance of conference proceedings in Computer Science, with these works comprising 78% of the collection, followed by monographs (8%), contributed volumes (4%), textbooks (3%) and other materials (7%).[8]

Over the years, the classification of LNCS as a journal, conference proceedings or book series has varied. The LNCS series offers comprehensive coverage and indexing in academic databases such as Elsevier's Scopus and Clarivate's Web of Science (WoS). Clarivate indexed LNCS from 1981 onwards in the Web of Science Core Collection.[9] Between 1999 and 2005, Clarivate listed LNCS in the Journal Citation Reports and assigned a journal impact factor. When Clarivate established the Conference Proceedings Citation Index (CPCI) database in September 2008, it moved LNCS to the new index.[9]

LNCS is classified in Scopus under the source type 'book series' and document type 'conference paper'. The source types covered in Scopus are either serial publications that have an ISSN (International Standard Serial Number) (e.g. journals, book series and conference series) or non-serial publications that have an ISBN (International Standard Book Number) (e.g. one-off book publications or one-off conferences). Document types are sub-units or components of source types and indicate the type of publication (e.g. journal article, conference paper or book).[10]

LNCS is readily available through various online platforms and academic databases, ensuring that researchers globally can access and cite LNCS. This availability enhances the discoverability, e-visibility, archiving, citability and research impact of the publication and contributes to the popularity of LNCS as a publication medium. However,

the Springer LNCS e-book series is a commercial, paywalled resource available for purchase as part of the Springer Nature Computer Science eBook Collection, which limits its accessibility compared to open-access publications. Authors are allowed to upload author-accepted versions of their papers on publicly available repositories, thus mitigating the paywall issue to some extent.[11] Springer also allows authors to publish substantially revised and extended versions of their LNCS papers in other outlets, provided that the original LNCS publication is acknowledged.[11]

For conferences to be considered for publication in the LNCS series, they must meet the following criteria: have an international programme committee, focus on a coherent set of topics that are of international relevance, and ensure a minimum of three reviewers per paper.[12] Furthermore, Springer proceedings should contain original research that has not been published or submitted elsewhere.[12]

Although LNCS is subsidy-bearing and accredited as a publication by the South African Department of Higher Education and Training (DHET)[13], its academic status and research significance as a discipline-specific publication venue for South African based Computer Science researchers are unclear. The problem statement is that it is uncertain to what extent Computer Science scholars in South Africa select LNCS as a publication channel for the dissemination of their research results and if it will continue to provide a suitable outlet for their future publications. Furthermore, it is also uncertain what the citation impact of LNCS is compared to other Computer Science journals in South Africa.

The main research question was: What are the publication output and authorship patterns of South African based authors who publish in LNCS? The sub-questions were:

- Which South African institutions contribute the most to the global publication output of LNCS?
- What are the most popular subjects and topics of LNCS papers from South Africa?
- What is the collaboration behaviour of South African based authors who publish in LNCS?
- What institutions, countries and regions feature as the most significant collaboration partners of South African based LNCS authors?
- How does the publication output of South African based LNCS authors compare to the global publication rate in LNCS and the global rate in the category of 'Computer Science' and sub-category 'General Computer Science' (GCS) in Scopus? (LNCS is classified in the GCS sub-category.)
- How does the citation impact of LNCS papers from South Africa compare to the global citation rate of LNCS and the global rate in the category of 'Computer Science' and sub-category 'General Computer Science' in Scopus?
- What is the reputation and status of LNCS, and how do they impact the series as a future publication outlet of choice for South African based authors?

Answering the questions above could reveal the academic status and research significance of LNCS as a publication outlet for Computer Science researchers in South Africa.

We therefore aimed to explore whether LNCS is a popular research outlet for South African authors in Computer Science. To ascertain if LNCS provides a quality platform for future South African publications, it is necessary to provide a holistic picture of the status and reputation of LNCS as a publication venue.

The scope of the article is to determine the involvement and relationship of South African authors with LNCS for the period 1973 to 2022. The number of South African papers is compared with those from other countries. To determine the impact of the South African papers, the citation metrics were also explored and compared to a DHET-accredited South African Computer Science journal.

The article makes a contribution by positioning LNCS in terms of other Computer Science journals. Determining the prominence and status of LNCS – globally and locally – gives an indication of the publication's standing as an outlet for Computer Science research. The research clarifies the contributions of South African based authors to the publication, in terms of both quantity and impact.

Literature review

Traditionally, Computer Science has had a conference-centric publication culture.[14-16] Conferences offer a fast publication cycle and immediate dissemination of cutting-edge findings in a rapidly evolving field of emerging technologies. In a historical investigation into the development of modern Computer Science publications and conference-based publication practices, Bouma-Sims[17] observes that there was an increase in conference publications in the 1980s, with publications in reputable conference proceedings being valued as much as (or even more than) articles in journals. This situation, however, complicates the application of traditional performance metrics in the research assessment of Computer Science researchers.[18,19] Zhang and Glänzel[20] confirm the importance of LNCS as a core Computer Science publication channel. Although proceedings papers receive fewer citations and the citation impact is lower than that of research articles[20], proceedings papers have remained the main publication channel in Computer Science over the past 10 years. The latest Scopus SciVal data show that from 2013 to 2022 there has been a total publication output of 4 462 139 with 41 819 764 citations and an average citation rate of 9.4 citations per paper. There were 2 473 808 (55%) conference papers compared to 1 658 367 (37%) journal articles in Computer Science and 8% were other publication types (see Supplement A[21]). In the General Computer Science subcategory, there was a total of 818 095 publications, with 159 501 citations and an average of 7.5 citations per paper. For GCS, there were 413 574 conference papers (50%) and 295 198 journal articles (36%), and 14% were other publication types (see Supplement A[21]).

However, Fortnow[22] argues that Computer Science is a mature discipline that needs to change its publication behaviour from a conference-based to a journal-based system. Halpern and Parkes[23] discuss the problems associated with the conference-based practice of publication in Computer Science. According to the latest 2022 Scopus SciVal Computer Science category data, the number of conference papers peaked in 2019 at 310 347 and declined to 281 906 in 2022, while the number of journal articles has been growing since 2013 and peaked in 2022 at 277 050, just slightly behind the conference papers. Looking at the sub-category of General Computer Science, the number of conference papers peaked in 2020 at 53 556 and declined to 36 152 in 2022, while the number of journal articles has been growing since 2013 and peaked in 2019 at 46 941 and declined to 37 823 in 2022 (see Supplement A[21]). These findings suggest that the conference-centric publication behaviour has already started to change into a journal-centric publication culture.

Scientometric and bibliometric analyses of Computer Science research output conducted in Argentina[24], Mexico[25], the Republic of Moldova[26], India[27], the Netherlands[28], China[29] and Malaysia[30] emphasise the importance of conference proceedings and LNCS as a core publication outlet for Computer Science research. Subject-specific reviews in the field of Geographical Information Systems[31], the Digital Economy[32], Living Labs and Human-Computer Interaction[33] conclude that LNCS is among the most popular publications for these subject domains.

Fiala and Tutoky[1] conducted a bibliometric assessment of 1.9 million Computer Science journals and conference papers indexed in the WoS and the CPCI for the time frame 1945 to 2014 – an extensive investigation which highlighted the reliance on conference publications in the field of Computer Science. The results indicated that 56% of papers were published as proceedings papers and 35% as journal articles – the latter received 75% of citations, compared to 11% for the former.[1] Journal articles received on average 13.4 citations per article compared to 1.2 for conference papers.[1] The researchers found that most Computer Science papers were published in LNCS and established that the average number of citations per paper for LNCS was 3.6 for the period under study (1945–2014).[1] The most productive subject areas were Artificial Intelligence (31.8%), Theory and Methods (30.3%) and Information

Systems (26.6%), while the United States of America (USA) (24.8%), China (13.7%) and the United Kingdom (UK) (5.7%) were the countries with the most publications.[1] The study showed that LNCS papers (11 259) comprised 0.6% of the total papers (1 922 625) published in Computer Science for the period 1945 to 2014.

In their study of Chinese publications in LNCS, He and Guan[29] analysed 5916 conference papers by Chinese authors between 1997 and 2005: more than half of the papers in Computer Science from China were published in LNCS. He and Guan's analysis also showed a trend of many publications with few citations and little impact. As their results showed, the number of papers by Chinese authors published in LNCS had increased in the time frame investigated, especially since 2004, but citations of the papers remained very low.[29] Authorship patterns indicated a preference for jointly authored papers (97%) over single-authored papers (3%). Also, the Chinese researchers preferred domestic collaboration or co-authoring with fellow Chinese researchers to international collaboration.[29]

South African research studies into the Computer Science research landscape are sparse[34-36], but two recent South African Computer Science bibliometric assessments notably emphasise the popularity of LNCS with South African scholars[2,3].

Parry[3] conducted a comprehensive scientometric investigation into Computing research in South Africa, using the Elsevier Scopus citation-enhanced database. The data set of 11 180 records included journal articles, books, book chapters and conference proceedings of researchers affiliated with South African universities for the period 2008–2017.[3] Parry's study revealed that Computing research in South Africa had increased by 172.61% over 10 years. Conference papers were the most popular publication format (61.40%), followed by journal articles (36.10%), book chapters (2.33%) and books (0.23%).[3] LNCS ranked third in the 25 most prominent publications for South African Computing research. Parry[3] calculated that the mean citation rate per publication for South African Computing research was 4.67 and that 39.19% of Computing publications had no citations. Conference papers accounted for 26.04% of the citations and journal articles for 73.18%, compared to books at 0.78%.[3]

A scientometric assessment of Computer Science in South Africa by Mouton et al.[2] for the period 2005–2020 concluded that LNCS is the predominant publication choice for local Computer Science researchers. They analysed 3441 papers in 472 publications retrieved from the SA (South African) Knowledgebase database of DHET subsidy-earning publications (see Supplement B and C[21]). The adapted data (Table 1)[2] underscore the popularity of conference proceedings as a publication outlet for this discipline, with 6 of the top 20 publication outlets being conference proceedings and 14 being journals.

In South Africa, the DHET funding that a university receives is partially based on the research output units produced by a university and is guided by the 2015 DHET Research Output Policy.[37] LNCS is subsidy-bearing and accredited as a publication by DHET.[13,38] At present, there are seven DHET-approved journal lists. The DHET Scopus journal list includes LNCS. The inclusion of the Scopus list as a DHET journal list was approved from 2016. Before 2016, LNCS papers were submitted to DHET as publications in conference proceedings.

The global publication behaviour in the field of Computer Science prioritises conferences over books or journals. However, this poses significant challenges for South African Computer Science researchers who are required to adhere to the journal-centric subsidy model set by DHET. The South African National Research Foundation (NRF) acknowledges the significance of conference papers as valuable research outputs in the field of Computing, although DHET places a higher emphasis on journal papers and considers them superior.[37] For each article published in a DHET-accredited journal, subsidy is almost guaranteed when claimed, compared to conference papers and book chapters where subsidy may be awarded if DHET is convinced of the standard of the peer-review process based on the details in the portfolio of evidence that should accompany the claim.[37] Conference papers are worth half of a journal article in terms of DHET subsidy. A research paper published in an accredited publication is subsidised as a single unit (1 research output unit), compared to papers published in approved conference proceedings that are allocated a maximum of 0.5 units.[38] DHET defines approved conference proceedings as "those which appear in approved conference lists or other approved indices"[38].

Table 1: Top 20 popular publication outlets for South African based researchers in Computer Science

Publication name (Publisher)	Document type	Paper count
Lecture Notes in Computer Science (Springer)	Proceedings	337
South African Computer Journal (SAICSIT)	Journal	201
IEEE Access (IEEE)	Journal	161
Communications in Computer and Information Science (Springer)	Proceedings	132
Advances in Intelligent Systems and Computing (Springer)	Proceedings	76
Scientometrics (Springer)	Journal	59
IFIP Advances in Information and Communication Technology (Springer)	Proceedings	54
Discrete Mathematics and Theoretical Computer Science *(Maison de l'informatique et des mathematiques discretes)* (Springer)	Journal	51
Bioinformatics (Oxford)	Journal	47
Computers and Security (Elsevier)	Journal	47
Mathematical and Computer Modelling (Elsevier)	Journal	39
Computers and Chemical Engineering (Elsevier)	Journal	34
Electronic Journal of Information Systems Evaluation (Academic Conferences International)	Journal	34
Lecture Notes in Artificial Intelligence (Springer)	Proceedings	34
Theoretical Computer Science (Elsevier)	Journal	33
Computers and Education (Elsevier)	Journal	30
Journal of Combinatorial Optimization (Springer)	Journal	30
Journal of Molecular Modeling (Springer)	Journal	29
Lecture Notes in Business Information Processing (Springer)	Proceedings	29
Structural and Multidisciplinary Optimization (Springer)	Journal	28

Source: Mouton et al.[2] with permission

Conference papers that are not published in DHET-approved conference proceedings listed on the DHET-accredited list, must adhere to DHET prerequisites.[38] For instance, a minimum of 60% of contributions published in the conference proceedings should originate from multiple institutions. The primary objective of the conference must be to facilitate the widespread dissemination of original research and new advancements in the relevant field. All submitted papers must undergo rigorous peer review before being accepted for publication. Evidence of the peer review should be provided for subsidy claims. Additionally, DHET mandates that the conference should have an editorial board and/or organising committee, comprising a substantial majority of members from diverse institutions, demonstrating expertise in the respective subject area.[38] The preference for LNCS as a publication outlet among South African researchers may stem from the fact that LNCS is an approved DHET-listed publication[13],

facilitating smoother DHET subsidy claims and rendering a full research output unit.

In order to determine to what extent South African authors have selected LNCS in the past as a publication channel for disseminating their Computer Science research results, and the reasons therefor, this article reviews their publication output numbers in LNCS for the period 1973–2022, as well as the related citation impact, authorship patterns and collaboration behaviour.

Methodology

The article follows a bibliometric approach. Bibliometrics can be defined as "the use of statistical methods to analyse publications with the aim of measuring outputs of individuals, institutions, and countries, and identifying networks between them"[39]. Bibliometric data provide quantitative measures to assess the influence and research impact of academic publications and guide researchers with their publication outlet choices. This study is a quantitative analysis of the South African LNCS contributions for the period from 1973 to 2022. The selected time frame corresponds to the establishment of LNCS in 1973. The data collection occurred in June and July 2023, while the study encompasses the period leading up to 2022.

The Elsevier Scopus citation-enhanced database was selected as the bibliometric data-collection tool, due to the extensive retrospective coverage and availability of LNCS citation data. Scopus, as the largest curated citation database and a reliable high-quality bibliometric data source[40], has better coverage than the WoS when it comes to Computer Science related subjects[41]. Scopus SciVal data were also obtained for the period 2013–2022.

SciVal is an Elsevier research analytics product that uses the publications in the Scopus database as its data set. It provides a wide range of research metrics and has the ability to create reports, and compare and benchmark many different types of entities.[42]

The coverage of Computer Science in Scopus is estimated to be in the region of 60.59%.[42] Scopus uses the ASJC (All Science Journal Classification) subject scheme and classifies all computing-related literature into the broad category of Computer Science.[43] Scopus indexes approximately 2626 sources in the Computer Science subject area.[44] Table 2 lists the number of sources in the 13 sub-disciplines of Computer Science in Scopus.

LNCS is assigned to the subject category 'General Computer Science' and the publication is ranked 126th out of 233 by CiteScore metrics. CiteScore is based on the number of citations to documents (articles, reviews, conference papers, book chapters and data papers) in a journal over 4 years, divided by the number of the same document types indexed in Scopus and published in the same 4 years by that journal[42] (see Supplement D[21]). The 358 General Computer Science sources referred to in Table 2 include active and inactive sources, 233 of which are active (i.e. currently accepting and publishing new articles).

The Scopus database shows that a total of 8 102 462 documents were published globally in the field of Computer Science for the period 1973 to 2022 (Table 3). Of these, 6.40% (518 662) were LNCS papers. A total of 1 450 425 documents were published in the subcategory 'General Computer Science', of which 35.76% were LNCS papers. South African LNCS papers comprised 0.01% (1150) of the total Computer Science papers published globally and 0.08% of the papers published in the subcategory 'General Computer Science'.

A document search was conducted in Scopus using the LNCS Source-ID (25674) to retrieve the LNCS bibliographic data (ISSN:0302-9743 or

Table 2: Number of sources in Computer Science in Scopus

Scopus subject area: Computer Science – Total number of sources			2626
Scopus sub-categories for Computer Science	**Number of sources**	**Scopus sub-categories for Computer Science**	**Number of sources**
Artificial Intelligence	339	General Computer Science	358
Computational Theory and Mathematics	204	Hardware and Architecture	240
Computer Graphics and Computer-Aided Design	133	Human-Computer Interaction	170
Computer Networks and Communications	472	Information Systems	455
Computer Science (miscellaneous)	126	Signal Processing	158
Computer Science Applications	973	Software	561
Computer Vision and Pattern Recognition	121		

Table 3: Publication output in Computer Science in Scopus, 1973–2022

Scopus subject area: Computer Science – Total publication output			8 102 462
Scopus sub-categories for Computer Science	**Publication output**	**Scopus sub-categories for Computer Science**	**Publication output**
Artificial Intelligence (code=1702)	1 119 349	General Computer Science (code=1700)	1 450 425
Computational Theory and Mathematics (code=1703)	430 258	Hardware and Architecture (code=1708)	805 351
Computer Graphics & Computer-Aided Design (code=1704)	333 169	Human-Computer Interaction (code=1709)	439 050
Computer Networks and Communications (code=1708)	805 351	Information Systems (code=1710)	1 003 713
Computer Science (miscellaneous) (code=1701)	173 671	Signal Processing (code=1711)	739 517
Computer Science Applications (code=1706)	2 802 246	Software (code=1712)	1 644 553

Table 4: Top 50 countries contributing to *Lecture Notes in Computer Science*, 1973–2022

Country	Number of papers	Country	Number of papers	Country	Number of papers
USA	86 617	Belgium	7706	Hungary	2376
China	66 050	Portugal	7386	Romania	2113
Germany	56 062	Russian Federation	7258	Malaysia	2023
France	40 422	Israel	7246	Chile	1862
United Kingdom	39 859	Sweden	7235	Tunisia	1680
Italy	28 671	Taiwan	7203	Iran	1516
Japan	28 664	Greece	6523	Colombia	1441
Spain	23 922	Denmark	6100	Vietnam	1360
Canada	19 425	Singapore	5934	Thailand	1251
Australia	16 468	Hong Kong	5891	Bulgaria	1219
Netherlands	16 167	Czech Republic	5840	Luxembourg	1217
South Korea	15 949	Finland	5547	Slovakia	1169
Poland	12 212	Norway	4783	**South Africa**	**1150**
India	11 317	Mexico	4069	Argentina	1122
Austria	10 013	Ireland	3942	Slovenia	1120
Switzerland	9960	Turkey	2814	Saudi Arabia	1064
Brazil	9095	New Zealand	2811		

E-ISSN:1611-3349). The time frame of the search was limited to the period 1973–2022, with a total of 518 662 papers published globally in LNCS during that period.

To analyse and compare the productivity patterns, the results were further refined by limiting the study to papers only from South Africa. There were 1150 papers with a South African affiliation (i.e. 0.22% of the total of 518 662 LNCS papers published internationally). The Scopus data were exported into an MS Excel spreadsheet format for analysis. Using the 'Analyse search results' function in Scopus, the results were analysed according to author, affiliation and country, and then ranked by the top affiliations and countries. The 'Export refine' option in Scopus was used to export the keywords, countries, affiliations and number of papers to MS Excel. The total number of papers per annum for LNCS were exported to MS Excel and the total number of citations per annum was calculated. The average citations per paper per annum were calculated by dividing the citation count (number of citations) by scholarly output (number of papers).[42] The collaboration patterns of South African based authors were also analysed. All LNCS South African papers were assigned a collaboration type by Scopus, based on affiliation information[42]:

- International collaboration: global collaboration between authors from different countries
- National collaboration: collaboration between authors from different institutions within the same country
- Institutional collaboration: collaboration between authors from the same institution
- Single authorship: sole-authored paper with no collaborators

Results

Authors from a total of 159 countries made contributions to LNCS between 1973 and 2022. Table 4 presents the top 50 countries, ranked by their contributions. South Africa ranked 47th out of 159, with a publication count of 1150 research papers (see Supplement E[21]). It seems that this rank is quite stable when compared to more recent periods. In the decade 2003–2012, South Africa retained its 47th place, but in the decade 2013–2022, it moved up slightly to 44th place (see Supplement F[21]).

Figures 1–6 show the global and South African LNCS output and citation impact (1973–2022). Global publication output in LNCS has grown exponentially since its inception, from 92 in 1973 to 20 372 papers in 2022, while South African publications increased from one paper in 1978 to 57 in 2022 (Figures 1 and 2). South African based authors did not publish in LNCS between 1973 and 1977, nor in 1979, 1981–1989 and 1992. A possible explanation for this finding is the country's isolation and the academic sanctions that were in place during the apartheid era. During the culmination of the era of apartheid in the 1980s, there was widespread support for an academic boycott. This boycott involved various tactics, such as journals and publishers refusing to accept or publish manuscripts originating from South Africa, exclusion of South Africa from participation in international scientific conferences[45], denial of entry visas to academics, international scholars declining to visit South Africa or to collaborate with South African researchers, as well as restricted access to information resources like books, journals, computer software and databases[46]. However, academic sanctions were gradually relaxed from 1990, leading to an increase in South African participation in the international scholarly arena. Figure 2 reflects this increase by showing the exponential growth of South African LNCS publications since 1994.

From 1993 onward, there were regular annual contributions with steady annual growth. Figures 1 to 4 compare the number of global and South African LNCS papers and citations. Figure 5 compares the percentage of South African citations with the percentage of South African papers, and Figure 6 the global and average citations per paper per year. The graphs provide a visual way to gain insight into South Africa's contributions to LNCS. Although all the data available up until 2022 were collected, it should be noted that citations take time to accumulate. Therefore, the data of the last 2 years cannot be used as a reliable indication of any current or future trends.

As shown in Figures 1 and 2, the total number of global LNCS papers grew exponentially until 2006 when it stabilised at between 20 000 and 25 000 p.a., while the South African LNCS papers seem to have gained

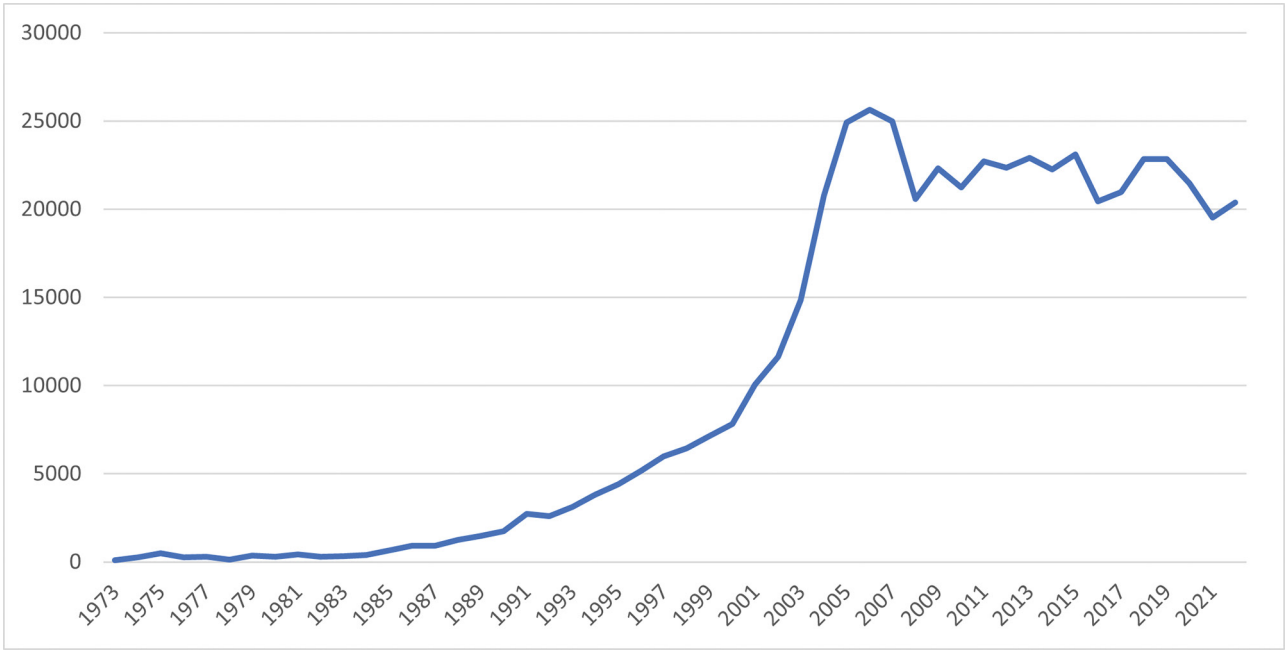

Figure 1: The annual number of global papers published in *Lecture Notes in Computer Science* from 1973 to 2022.

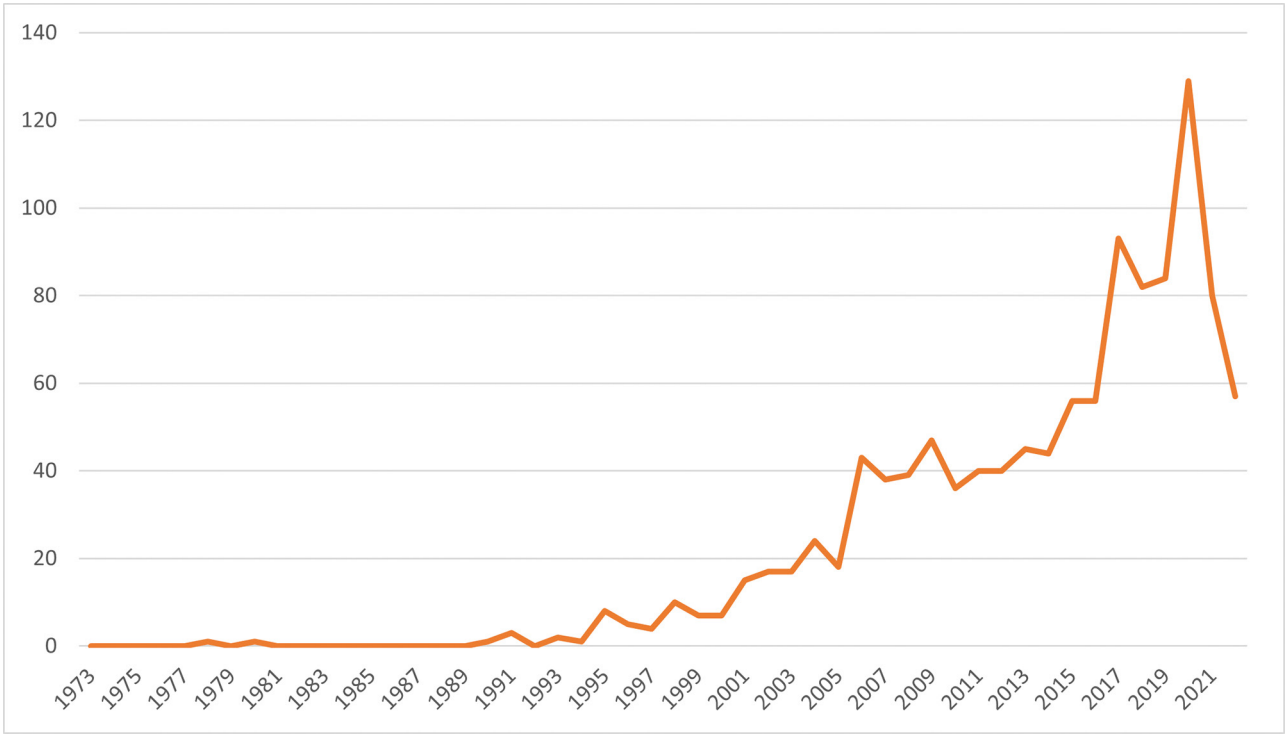

Figure 2: The annual number of papers from South Africa published in *Lecture Notes in Computer Science* from 1973 to 2022.

momentum from around 2005 with spikes in 2006, 2017 and 2020 (129 papers), and then declined again in 2021–2022 (this may be due to the COVID-19 pandemic, and it is not yet clear if the declining trend will continue or if the South African numbers are stabilising around 60 p.a.). The number of annual South African publications peaked 14 years after the global peak. The delayed growth in South African publications may be due to the addition of the Scopus list to the approved DHET list in 2016. This development possibly stimulated a surge in submission of conference papers to LNCS by authors from South Africa from 2016.

The annual number of global LNCS citations grew steadily until 2006 but seems to be diminishing, while the number of South African citations peaked in 2008 and then declined, and seems to be stabilising around 400 p.a. (Figures 3 and 4). It seems that the overall citation impact of LNCS is declining, which prompts a recommendation that authors should also consider other journals with stable or growing citation impact.

The 1150 South African papers were cited in Scopus 6968 times, compared to the global citations of 4 926 601 (i.e. 0.14%). Of the 1150 papers by South African based authors, 836 (73%) had citations and 314 (27%) did not. When comparing the percentage of South African papers in LNCS with the percentage of South African LNCS citations, it is clear that the growth of the number of citations is closely aligned with the number of publications, suggesting that the relationship is quite stable

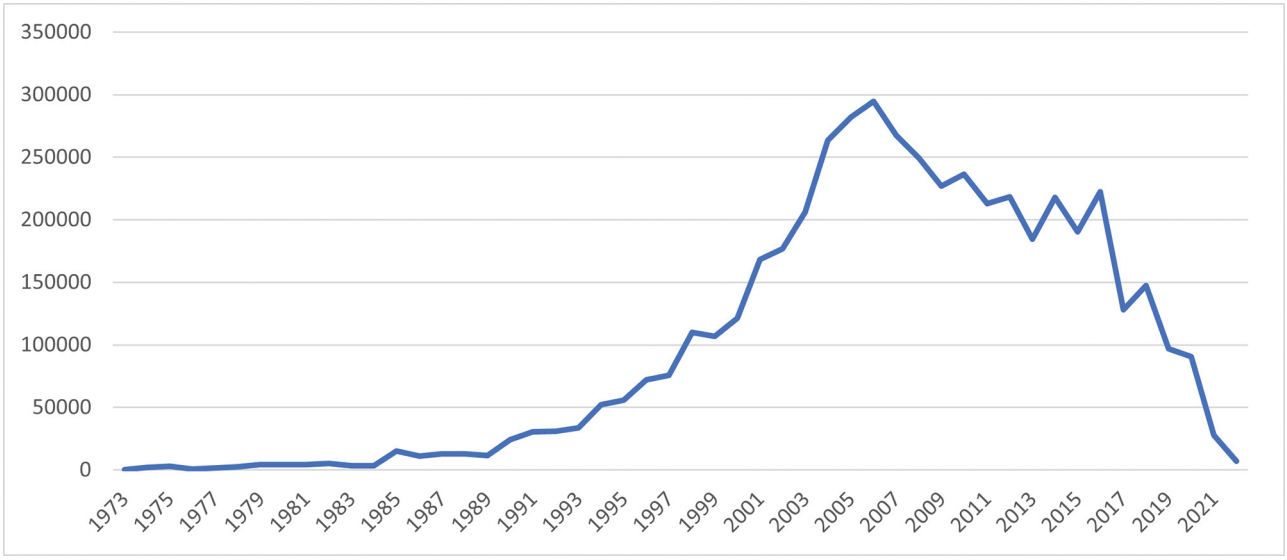

Figure 3: The annual number of citations to global *Lecture Notes in Computer Science* papers.

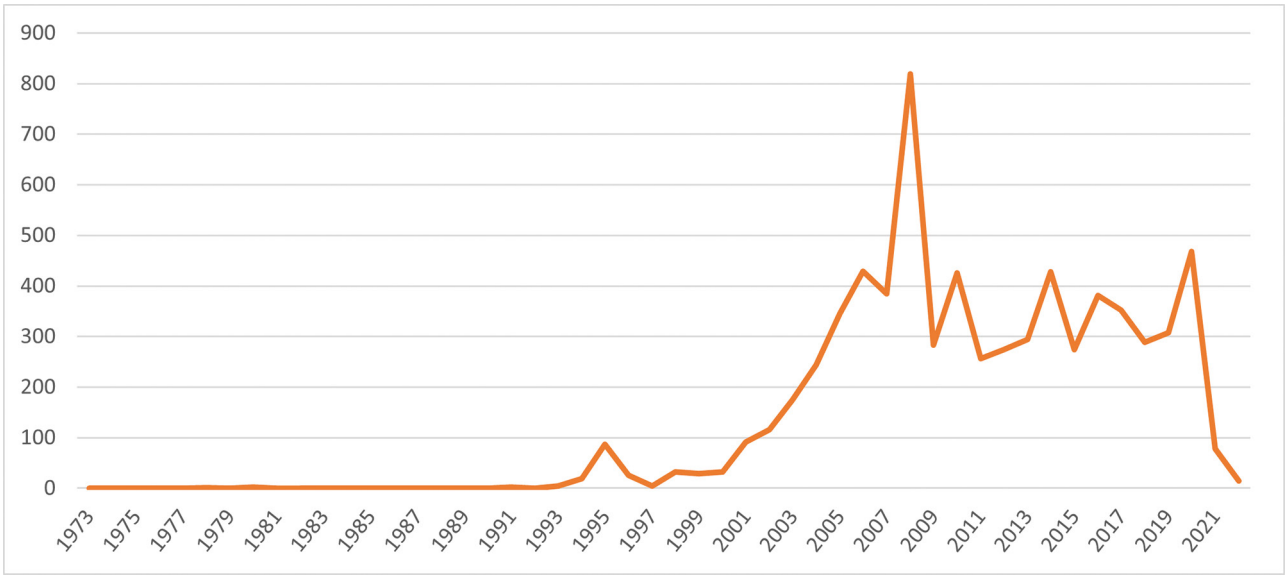

Figure 4: The annual number of citations to *Lecture Notes in Computer Science* papers from South Africa.

(Figure 5). A possible trend that seems to have emerged since 2018 is that South African papers are attracting more citations, almost equalling the percentage of paper numbers in 2020.

When comparing the percentage of the total LNCS average citations per paper with the South African LNCS average citations per paper, it seems that the average number of citations is diminishing but that the South African average is converging to the overall average (Figure 6). This may indicate that the quality of South African papers is becoming comparable to that of global papers and that South African papers are attracting an equivalent number of citations (see Supplements G–J[21]).

Table 5 shows the most productive South African institutions by the number of papers published in LNCS for the period 1978–2022. This information shows that authors affiliated with some of the country's top-ranked universities have published the most in LNCS. This finding may suggest that there has been, and still is, a significant place for LNCS as a Computer Science publication outlet in South Africa.

Figure 7 shows the collaboration behaviour of South African based authors by the number of papers published in LNCS for the period 1978–2022. Of the 1150 papers from South Africa, 492 (43%) represented institutional collaboration, 424 (37%) international and 127 (11%) national collaboration, while 107 (9%) were single-authored. Overall, LNCS authors from South Africa adopted a collaborative publication culture, with 107 (9%) single-authored and 1043 (91%) co-authored papers. The graph shows that LNCS provides a platform for South African based authors to collaborate with international scholars, as well as with other academics in their home institutions. This may explain the journal's popularity. Surprisingly, national collaboration seems not to be a preferred way of authoring papers in South Africa compared to the Chinese scenario discussed above in which researchers preferred domestic collaboration over international collaboration.[29] Sole authorship is also not popular, which may be explained by a culture in Computer Science of supervisors co-authoring with their postgraduate students (see Supplements K–O[21]).

Scholars from 160 institutions co-authored with South African based LNCS authors (see Supplement P[21]). Figure 8 depicts the international (regional and country) distribution of the LNCS papers contributed by South African scholars and researchers who collaborated internationally. South African based authors collaborated with scholars from 68 countries, with the top five international collaboration partner countries being the UK, Germany, the Netherlands, the USA and Italy (see Supplement Q[21]).

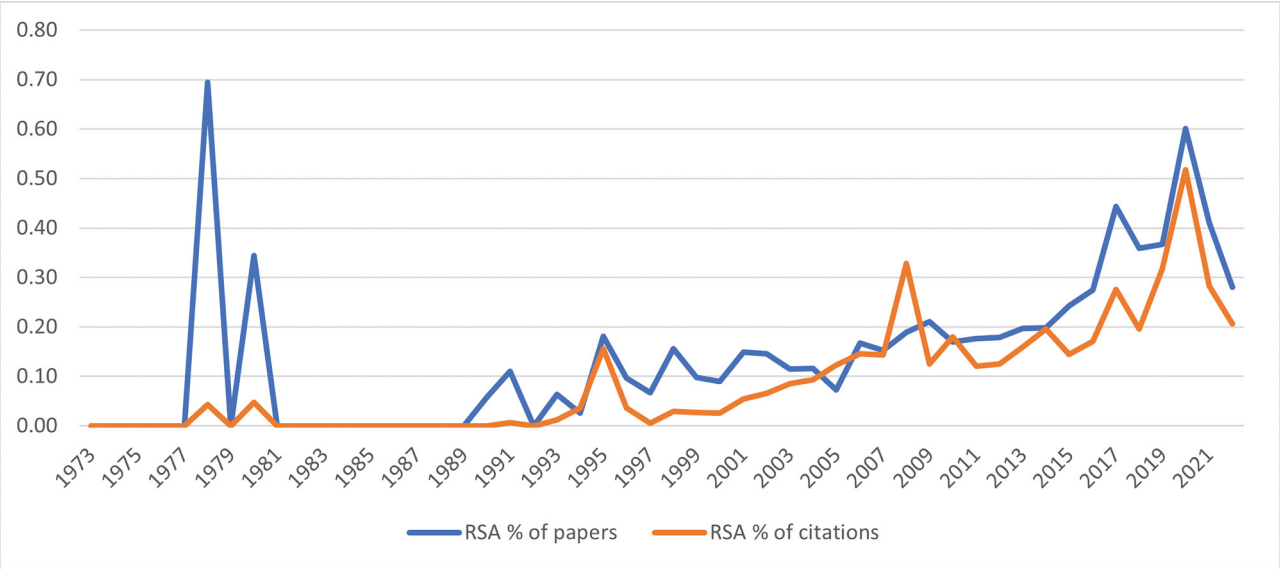

Figure 5: A comparison of the percentage of South African (RSA) papers in *Lecture Notes in Computer Science* (LNCS) with the percentage of South African LNCS citations.

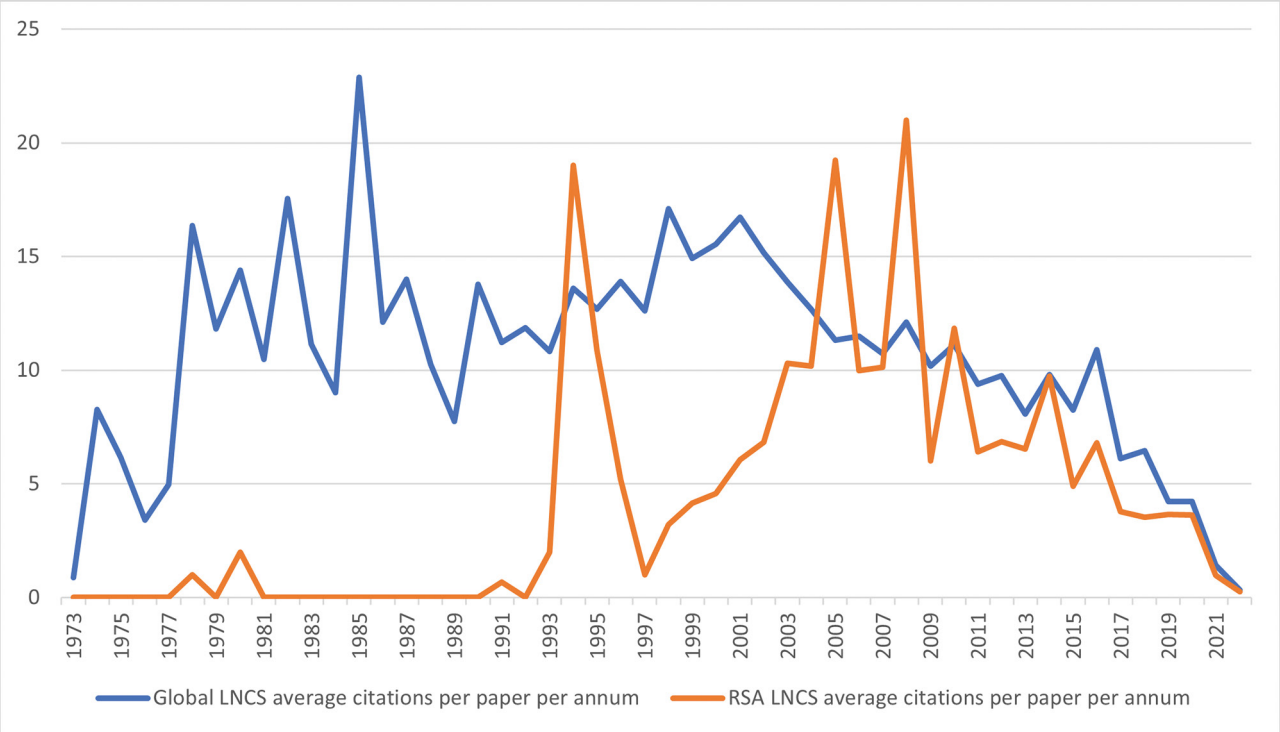

Figure 6: A comparison of the global *Lecture Notes in Computer Science* (LNCS) average citations per paper with the South African (RSA) average citations per paper per annum.

Over the past 44 years, South African based authors have shown a preference to collaborate with scholars in Europe (430), followed by those in North America (64), and less so with scholars in Asia (53), elsewhere in Africa (48), Oceania (41), Latin America (31) and the Middle East (10).

Table 6 ranks the top 50 keywords assigned to papers by the number of papers that include those keywords. A total of 160 keywords were assigned to the 1150 LNCS papers from South Africa. 'Artificial intelligence' was the most used keyword, followed by 'computer science' and 'electronic commerce' (see Supplement R[21]). Artificial intelligence was also identified by Kotze and Van der Merwe[35], as well as by Fiala and Tutoky[1], as a topic that attracted a significant number of papers.

An integrated comparison of the productivity and citation metrics is useful to gauge South African based authors' contributions and impact. Table 7 provides such an integration. To enable an integrated, fair and accurate comparison, SciVal data for the period 2013–2022 were used. To account for a comparative South African context, data from the *South African Computer Journal* (SACJ) are included in the table. SACJ is the only dedicated Computer Science journal published in South Africa (see Supplements S–W[21]).

Table 5: Top South African contributors to *Lecture Notes in Computer Science* by affiliation (1978–2022)

Affiliation	Number of papers
University of Pretoria	210
University of Cape Town	188
Stellenbosch University	154
University of KwaZulu-Natal	151
University of Johannesburg	125
University of South Africa	91
Council for Scientific and Industrial Research	78
University of the Witwatersrand	74
Tshwane University of Technology	53
Meraka Institute	33
Nelson Mandela University	27
French South African Institute of Technology	20
University of the Western Cape	19
University of the Free State	16
Durban University of Technology	15
North-West University	14
Rhodes University	8
Vaal University of Technology	7
Cape Peninsula University of Technology	5

Discussion

Computer Science researchers could benefit from a shift in publication behaviour, specifically moving towards a more balanced approach by selecting journal papers over conference publications. There are several considerations associated with publishing in LNCS as opposed to journals. Although LNCS is a reputable publication, a paper that appears in this series may not attain the same level of research impact as a paper in a prestigious journal. Conferences typically have tight deadlines and limited timelines for peer review, compared to the longer review cycles of journals and adequate time for detailed feedback and multiple revisions.[47] LNCS papers undergo peer review, but the quality and consistency of the peer review may vary across different LNCS conferences or individual reviewers, making the peer review less rigorous than that of top-tier journals. LNCS has page and space limits and accepts full papers (12–15 pages) and shorter papers (6–11 pages).[12] Researchers can present more comprehensive, detailed and complete work in journals compared to LNCS. Furthermore, journal papers carry more weight than conference papers in individual researcher performance assessments.[19] Compared to publishing in LNCS, publishing in high-impact journals will enhance a researcher's academic reputation, funding opportunities and career advancement. LNCS papers are behind paywalls, which can limit access to researchers without Springer institutional subscriptions. Conference papers tend to become obsolete more quickly than journal articles[48], and the citations they generate are significantly lower[20], which can have a long-term negative impact on a researcher's Hirsch index (h-index), which measures an author's number of publications and citations. While a wide range of journal metrics exists for assessing scientific journals, comparable metrics for scholarly conferences are lacking. Standardised, universally accepted conference citation metrics or curated lists of reputable academic conferences to indicate the quality of conferences are not available.[37] Conference acceptance rates are often used as an evaluation methodology, with lower rates associated with thorough peer-review processes and reputable conferences.[49] However, these acceptance rates are rarely published, making them less accessible. For researchers with a diverse publication record, conference papers can be a complement or supplement to journal papers, but are not a replacement.

In fields where technology develops fast, quick publication turnaround times are important to allow authors to protect their intellectual property on innovative ideas. LNCS provides such a platform: a reliable and established series with short delays between submission and publication and a peer-review process similar to that of journals.

When one compares the average number of publications per author for the whole Computer Science category (all sub-fields and all publication types in the Scopus database), it seems that South African based authors (1.39) are considerably more productive than the global average (0.94) (Table 7). The same is true, and even more so, when one compares the productivity in the sub-field of General Computer Science (GCS) only: South Africa: 1.05 vs global: 0.69. However, South African LNCS authors' productivity (0.64) is slightly below – but very close to – the global GCS (0.69) and LNCS global (0.67) average number of publications per author. This result suggests that South African based authors' use of LNCS as a publication outlet is aligned well with the global pattern, and that LNCS is not overly used by them.

In terms of citations, however, the performance of papers from South Africa is somewhat disappointing. The average number of citations per publication for the whole Computer Science category (all sub-fields and all publication types in the Scopus database) for South African papers (7.5) seems to underperform somewhat compared

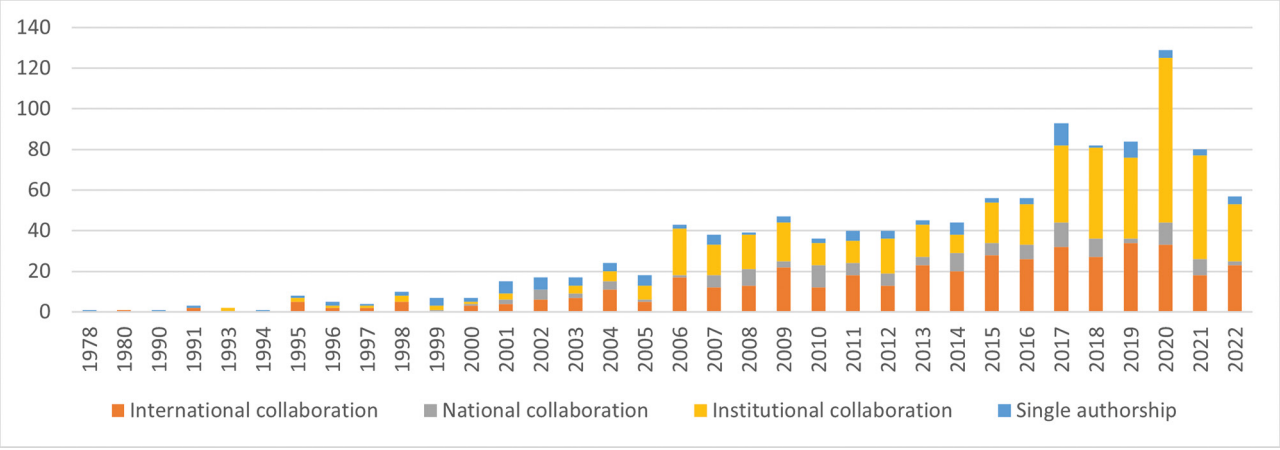

Figure 7: Collaboration behaviour of South African based authors of *Lecture Notes in Computer Science* papers, 1978–2022.

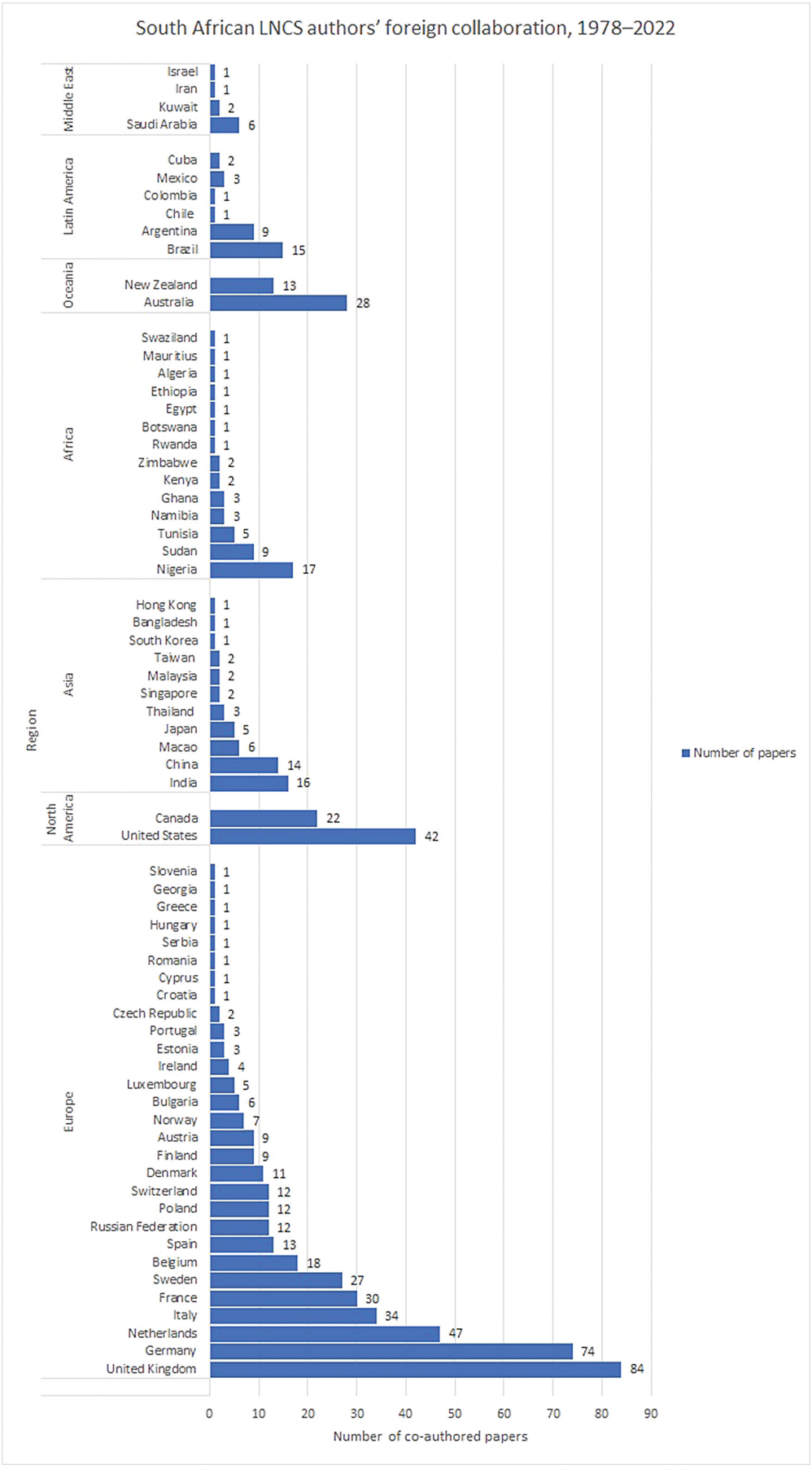

Figure 8: The distribution of international (regional and country) collaboration by South African based authors of *Lecture Notes in Computer Science* papers (1978–2022).

Table 6: Top keywords in *Lecture Notes in Computer Science* papers from South Africa

Keyword	Number of papers	Keyword	Number of papers	Keyword	Number of papers
Artificial Intelligence	172	Digital Libraries	36	Model Checking	26
Computer Science	75	Computer-Aided Instruction	35	Surveys	26
Electronic Commerce	72	Feature Extraction	34	Computer Vision	25
Information Use	72	Students	34	Data Mining	25
Computers	68	Computer Circuits	30	Pattern Matching	25
Algorithms	67	Machine Learning	30	Support Vector Machines	25
Human-Computer Interaction	60	Image Segmentation	30	Developing Countries	24
Semantics	60	Swarm Intelligence	30	Multi-Agent Systems	24
Learning Systems	53	Education	29	Social Networking (online)	24
Particle Swarm Optimization	51	Computational Linguistics	28	Evolutionary Algorithms	23
Optimization	47	Design	28	Learning Algorithms	23
Deep Learning	45	Ontology	28	Convolution	22
E-learning	41	Problem Solving	28	Engineering Education	22
Classification (of Information)	40	Knowledge Management	27	Multi-objective Optimization	22
Neural Networks	40	User Interfaces	27	Websites	22
Information Systems	37	Decision Making	26	Convolutional Neural Network	21
Computation Theory	36	Formal Logic	26	Graphic Methods	21

Table 7: An integrated comparison of publication productivity with citation impact (2013–2022) based on SciVal data

SciVal data 2013–2022	Publication output	Number of authors	Average number of publications per author	Citation count	Citations per publication	FWCI
Global – Computer Science category (all publication types)	4 462 139	4 730 259	0.94	41 819 764	9.4	1.06
South Africa – Computer Science category (all publication types)	21 298 (South Africa ranks 44th out of 220 countries)	15 275	1.39	159 501	7.5	0.92
Global – General Computer Science (all publication types)	818 095	1 183 354	0.69	5 881 007	7.2	1
South Africa – General Computer Science (all publication types)	3829 (South Africa ranks 49th out of 198 countries)	3 651	1.05	26 347	6.9	1.01
Global – LNCS	216 705	324 542	0.67	1 312 423	6.1	1.01
South Africa – LNCS	726 (South Africa ranks 47th out of 159 countries)	1142	0.64	2886	4	0.81
South African Computer Journal	123	195	0.63	469	3.8	0.26

FWCI, Field-Weighted Citation Impact; LNCS, Lecture Notes in Computer Science

to the global average (9.4). South African based authors fare better in the sub-field of General Computer Science (GCS): South Africa: 6.9 vs. global: 7.2. The global LNCS average number of citations per publication (6.1) is somewhat below the global GCS average (7.2), while the South African LNCS average (4) is considerably lower than both. This result suggests that, although South African LNCS authors' production is on par with global LNCS rates, their papers attract considerably fewer citations.

Field-Weighted Citation Impact (FWCI) is the ratio of the total citations actually received by the denominator output and the total citations expected based on the average of the subject field[42]:

- A FWCI of 1.00 indicates that the entity's publications have been cited exactly as would be expected based on the global average for similar publications.
- A FWCI of more than 1.00 indicates that the entity's publications have been cited more than would be expected based on the global average for similar publications.
- A FWCI of less than 1.00 indicates that the entity's publications have been cited less than would be expected based on the global average for similar publications.

The South African FWCI of 0.92 is below the global FWCI of 1.06, showing that South African publications were cited less than would be expected in the Computer Science category (all sub-fields and all publication types in the Scopus database). In the General Computer Science sub-field, the South African FWCI of 1.01 is on par with the global FWCI of 1.00 and equal to the global LNCS FWCI of 1.01. However, the FWCI of South African LNCS papers of 0.81 is below the global LNCS FWCI of 1.01. Although this score is better than the South African average number of citations – which probably says something good about the quality and reputation of South African contributions in LNCS – there is still room for improvement.

The outcome of the comparison above suggests possible reasons for the popularity of LNCS globally and in South Africa. Unfortunately, Scopus citation metrics do not distinguish between journal articles, conference papers and other publication types. It was therefore not possible to compare the various categories with each other, but it was possible to compare LNCS as a conference paper outlet in the GCS field with the trends identified for all publication types in the GCS field. While the average number of publications per author and the number of citations per publication is close to, but somewhat less than, the global GCS rate, LNCS's global FWCI is almost equal to the GCS rate. If one takes into account that LNCS publishes mainly conference papers, while the global GCS category encompasses all publication types, it seems that LNCS can be regarded as a middle-of-the-road outlet for GCS publications. In terms of the FWCI, it is positioned just above the 50th GCS percentile. Therefore, it can be deduced that LNCS probably behaves more like other GCS journals than other conferences. More research is, however, needed to compare the behaviour and performance of various publication types with each other.

Although South African publications in LNCS have attracted fewer citations than the global LNCS publications, the favourable FWCI suggests that LNCS provides an attractive venue for South African publications. The average number of publications per author, which is very close to the global LNCS number, suggests that South African based authors are seizing this opportunity. However, there is still room for improvement in terms of citations and citation impact, but, as suggested by Figure 6, it seems that the number of South African citations may already be converging towards the global LNCS average.

The *South African Computer Journal* (SACJ) is a DHET-accredited journal and the foremost regional publication channel for Computer Science in South Africa, enjoying widespread recognition within the academic community.[35] When comparing the citation metrics of LNCS to SACJ, LNCS outperforms SACJ.[42] In terms of CiteScore, LNCS achieved a score of 2.2 in 2022, whereas SACJ received a score of 0.9. In terms of the SCImago Journal Rank, LNCS obtained a score of 0.320, surpassing SACJ's score of 0.170 in 2022. The SCImago Journal Rank indicator is a measure of the prestige of scholarly journals that accounts for both the number of citations received by a journal and the prestige of the journals from which the citations come.[42] LNCS attained a Source Normalised Impact per Paper (SNIP) score of 0.542 in 2022, while SACJ obtained a score of 0.314. SNIP is a sophisticated metric that intrinsically accounts for field-specific differences in citation practices. It does so by comparing each journal's citations per publication with the citation potential of the field, defined as the set of publications citing that journal.[42] These metrics indicate that LNCS exhibits a higher journal performance than SACJ, which could contribute to the appeal of LNCS among researchers in South Africa.

This study highlights the collaborative nature of South African LNCS researchers, their preference for institutional and international collaboration, and their focus on topics related to artificial intelligence. A trend which emerged, namely that South African based scholars largely prefer to collaborate with European scholars (Figure 8), prompts the recommendation that they should look out for more collaborative research opportunities, not only within their own country but also across the globe, particularly in other parts of Africa. By way of collaborative research outputs in LNCS, Tunisia and South Africa, as the only two African countries among the top 50 countries contributing to LNCS during 1973–2022, can play a leading role in improving other African countries' research footprint. LNCS provides a platform for the publication of papers co-authored with other national and African scholars, as was the case in China (where national collaboration was preferred to international collaboration). These insights regarding collaboration provide valuable directions for future research and emphasise the significance of LNCS in the field of Computer Science. Due to space restrictions, it was not possible to include more detailed groupings broken down by institution or research group or to explore increasing or decreasing collaboration patterns in more depth. This limitation is acknowledged, and further research is suggested to uncover more detail regarding national and international collaboration patterns and trends, as the extent of the relevant data needed in this regard justifies a separate project.

Other related aspects that could be addressed in further research include the following. (1) To help contextualise the results of this article, further research is needed to determine how South Africa's rank in terms of the number of publications in LNCS (Table 4) corresponds with the number of PhDs graduating and the amount of research funding (in general and specific to Computer Science). (2) It may be enlightening to analyse from which specific conferences South African LNCS papers come and how this has changed over time. This will provide further insight into the publication trends discussed above by revealing meaningful patterns regarding the conferences that contribute the South African LNCS papers. (3) To better judge the status of LNCS as a platform for the publication of conference papers, there is a need for a comparative study of South African LNCS papers and South African papers in other conference proceedings or book series such as the Springer series *Communications in Computer and Information Science*. (4) Additional research is warranted to assess the prevalence of Computing researchers in South Africa as first authors in LNCS papers to shed light on the extent of collaborative research spearheaded by researchers in South Africa.

Conclusions

We investigated the involvement and relationship of authors based in South Africa with LNCS for the period 1973–2022. Of the total of 518 662 LNCS papers published globally during the years in question, South African based authors contributed a share of 0.22%, or 1150 papers. Local researchers' publication contributions to LNCS showed a consistent upward trend from 1993 to 2022. Authors from South Africa who published in LNCS preferred to collaborate, with 91% of papers being co-authored. Institutional collaboration (43%) was the most prevalent co-authoring style, followed by international (37%) and national collaboration (11%). The regional analysis showed that Europe was the most significant collaboration partner for local LNCS researchers, followed by North America and Asia. The top five international collaboration partner countries of the LNCS authors from South Africa were the UK, Germany, the Netherlands, the USA and Italy.

The keyword analysis showed that artificial intelligence was the topic of most of the South African LNCS papers.

The citation impact of South African LNCS papers was lower (6.06) than that of global LNCS papers (9.5). Of the 1150 papers from South Africa, 73% had citations and 27% did not. The South African citations represent 0.14% of the global LNCS citations. These metrics compare relatively well to those of journals, and probably much better to other conference proceedings, especially in the South African context.

While the integrated comparison of output numbers and impact showed that South African authors' productivity is on par with that of international scholars, the number of citations per publication is less than that of global scholars. The FWCI confirms that South African publications were cited less than would be expected based on the global average for similar publications.

Overall, the results indicate that LNCS remains a popular publication outlet for Computer Science researchers in South Africa because it has gained and maintained a high scholarly status over the past 50 years. It is a reputable and indispensable publication dissemination platform for Computer Science research, both globally and locally. Proceedings papers remain the most popular publication medium for Computer Science researchers, although there is a trend to find a more equal distribution. LNCS provides a quality platform or outlet for future publications from South African scholars and researchers. However, because LNCS attracts fewer citations than other accredited journals, with the number of citations on the decline, authors are encouraged to explore alternative outlets that offer stronger and more consistent citation impact. Given a seemingly strong reliance on conference publications with shorter papers and much more limited peer review, South African authors should aim and work to compete in a more rigorous and competitive journal-publication world at this stage.

Further investigation is needed to assess the scholarly influence and performance of LNCS (conference proceedings) when compared to other conference proceedings and journals. Conducting a survey among Computer Science researchers to explore the factors influencing their choice of LNCS as a publication venue would also provide valuable insights.

Acknowledgements

This research was supported in part by the National Research Foundation (NRF) of South Africa (grant number 132180) and the Research Professor Support Programme of the University of South Africa (Unisa). The grantholder acknowledges that opinions, findings and conclusions or recommendations expressed in the article are those of the authors and that neither the NRF nor Unisa accept any liability whatsoever in this regard. We also acknowledge valuable feedback received from the peer reviewers and editors.

Competing interests

We have no competing interests to declare.

Authors' contributions

F.N.: Conceptualisation; methodology; data collection; sample analysis; data analysis; validation; data curation; writing – the initial draft; writing – revisions; project leadership; project management; funding acquisition. J.H.K.: Conceptualisation; methodology; data collection; sample analysis; data analysis; validation; data curation; writing – the initial draft; writing – revisions; project leadership; project management; funding acquisition.

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