The National Research Rating System in South Africa: The Past Impacts the Future

Eder Kikianty and Loyiso Nongxa

1. Introduction

In the 19th century, mathematics research in South Africa (SA) grew out of the scientific activities of the Royal Observatory at the Cape of Good Hope and the mining industry in the Witwatersrand area. The start of the 20th century witnessed some prominent South African (SA) mathematicians who made significant contributions in mathematics. For example, Stanley Skewes,[1] a student of John Edensor Littlewood, worked on the prime-counting function.

The legalisation of apartheid in 1948 brought racial segregation to every aspect of life in SA, including education and the university system. The Bantu Education Act of 1953 discouraged the Black population from studying mathematics. The academic boycott of SA in the 1960s isolated SA mathematicians from international research and scholarships.

In 1984, the SA national rating system was introduced to identify and recognise scientists for excellence in research, and to provide them with sufficient financial support to pursue their own research. It is a peer-reviewed process and shares some similarities with the Research Assessment Exercise/Framework in the United Kingdom, except that the "rankings/ratings" are focused on individuals rather than departments. With this support, the mathematics research in SA started to flourish.

We provide a contextual and historical background for an analysis of the ongoing and long-term influence of the rating system. Specifically, we highlight the socio-political circumstances over the last seventy years which have shaped (and continue to shape) the mathematics research landscape in SA. The outcomes of the rating process provide some insights into the strengths, as well as the glaring gaps, in the SA mathematics[2] research profile. By examining the profile of young researchers who have been successful in gaining a rating, we identify a worrisome trend which may not augur well for the future vibrancy and strength of mathematics in SA.

2. Apartheid and the Academic Boycott of South Africa

The National Party came to power in SA in 1948 and legalised apartheid. This development had a profound and enduring impact on mathematics research in SA. Key to the legislation was the fact that South Africans would have different rights and privileges based on their race. The Population Registration Act (No. 30) of 1950 established mechanisms for determining and registering the race of all South Africans. Under the terms of this Act, all residents of SA were to be classified as "White," "Coloured,"[3] or

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[1] *Skewes studied in Cambridge in the 1930s and rowed with Alan Turing. They later wrote a joint paper, "On a Theorem of Littlewood," but it was never published* [Tur92, p. XIV].

DOI: https://doi.org/10.1090/noti2419

[2] *Throughout the text, the terms "mathematics" and "mathematics research" (accordingly, "mathematicians") include the research areas of pure and applied mathematics, statistics, and (in some cases) computer science.*

[3] *The term "Coloured" refers to the population group that emerged in the Cape in the 17th and 18th centuries as a result of contact between Africans, Malays,*

"Native" (later called "Bantu") people. Indians, whom the National Party refused to recognise as permanent inhabitants of SA, were later included in 1959 [CW13, p. 49]. The most damaging legislation [CW13, p. 52] was the Bantu Education Act (No. 47) of 1953, a segregation law that enforced racially separate educational facilities. Bantu education would mould Africans into compliant citizens and productive workers [CW13, p. 55].

Since then, mathematics education, for Blacks[4] in particular, has not been in a healthy state. The Minister of Native Affairs at the time, Hendrik Verwoerd, in a speech delivered on September 17, 1953, on the Second Reading of the Bantu Education bill, stated [VAK05, p. 310]: *"When I have control over native education I will reform it so that the Natives will be taught from childhood to realise that equality with Europeans is not for them. People who believe in equality are not desirable teachers for Natives . . . What is the use of teaching the Bantu child mathematics when it cannot use it in practice? That is quite absurd."*

Apartheid laws created a totally divisive society that emphasized the differences between people [Nol91, p. 206]. These policies meant that Black students were discouraged from taking mathematics as a subject. Many African students were never exposed to mathematics because it was not offered at their schools [VAK05, p. 310]. The situation was much worse for Black women, who suffer from lower levels of education and lack of employment opportunities[5] [Nol91, p. 212]. It is often remarked that South African women suffer a triple yoke of oppression: gender, race, and class [Nol91, p. 203].

In 1959, the passing of the Extension of University Education Act formalised the separation of universities by race and ethnicity. The university system was thus fragmented and reflected the apartheid planning: English-medium and Afrikaans[6]-medium universities, often grouped as White universities; new ethnic universities for certain African groups; and separate universities for Coloured and Indian students. The Act made it an offence, for example, for White universities to admit Black students without the approval of the relevant Government Minister.[7] In addition to racial segregation, there was also a binary system of traditional universities versus technikons.[8] For many of the smaller, rural universities and technikons, mathematics teaching was mainly focused on undergraduate levels and ancillary courses for students whose qualifications required one or two years of post-school "applicable" mathematics. At a number of institutions, it was not uncommon for people to be employed and teach throughout their careers with only a four-year university qualification, and consequently very few of them were engaged in research. This legacy lingers on up to this day.

SA became a republic in 1961, with Verwoerd, the intellectual architect of apartheid, as the Prime Minister. SA hoped to remain a member of the Commonwealth, but because of its apartheid policies, its membership was strongly opposed by other members. It led to SA leaving the Commonwealth in 1961. Implementation of the "Separate Development" plan[9] was accelerated and, among other things, led to the creation of self-governing homelands for African ethnic groups, some of which opted for pseudo-independence in the 1970s. The Bantu Homelands Citizenship Act of 1970 decreed that all Africans were to become citizens of their ethnic homelands and treated as foreigners in White SA. This was even in cases where they had never lived in those areas.[10] Very few other countries in the world recognised these as independent states and it made international travel difficult to impossible for many South Africans of African ancestry.[11]

The academic boycott[12] of SA was part of a broader international campaign[13] aimed at pressuring the SA regime to dismantle the apartheid system. The objectives of the boycott included: discouraging academics from collaborating with SA scientists; discouraging scientists from travelling to SA or refusing SA researchers entry to other countries to attend international conferences; and discouraging international academic associations from holding their conferences in SA.[14] Those that ignored the call for the academic

and Europeans. Despite partial European heritage, they were subjected to most apartheid legal restrictions [CW13, Glossary].

[4]*The term "Black" is often used to denote South Africans of non-European ancestry, although, under apartheid, some groups had the status of "honorary White."*

[5]*Black women were mainly employed as agricultural and domestic workers.*

[6]*Afrikaans is the language spoken by the (largely) Dutch settlers of the Dutch Cape Colony, which arose through a gradual divergence from Dutch dialects in the 18th century.*

[7]*For details, see: P. O'Malley, Extension of University Education Act No. 45, Nelson Mandela Centre of Memory,* `https://omalley.nelsonmandela.org/omalley/index.php/site/q/03lv01538/04lv01828/05lv01829/06lv01898.htm`.

[8]*Similar to the polytechnics in the UK in the 1970s.*

[9]*The basic principle of this plan was to grant Blacks their rights and freedoms only within the confines of their designated homeland. For details, see:* `https://www.sahistory.org.za/article/history-separate-development-south-africa`.

[10]*For details, see: P. O'Malley, Bantu Homelands Citizen Act No. 26, Nelson Mandela Centre of Memory,* `https://omalley.nelsonmandela.org/omalley/index.php/site/q/03lv01538/04lv01828/05lv01829/06lv01944.htm`.

[11]*The second author was issued with a special travel document in order to enter the UK and take up the Rhodes scholarship at Oxford University in 1978.*

[12]*The African National Congress (ANC) called for an academic boycott in 1958 and British scholars responded with a formal declaration (archived on the website of the ANC).* `https://web.archive.org/web/20140107065300/http://www.anc.org.za/show.php?id=6896`

[13]*Other pillars included economic, financial, and cultural sanctions.*

[14]*See:* `https://www.sahistory.org.za/article/south-africas-academic-and-cultural-boycott`.

boycott visited mainly the White universities; and thus the boycott created a greater negative impact on the ethnic universities and Black academics. During this period, a number of White academics emigrated, especially to the UK, the USA, Australia, and Israel. The enduring impact of this boycott is the ongoing intellectual and academic isolation of SA mathematicians from small and formerly ethnic universities.[15]

3. The National Rating System

The rating system was introduced in 1984 by the Council for Scientific and Industrial Research (CSIR). It was born out of a necessity to improve the research landscape in SA which was negatively impacted by, among other things, the academic boycott. We start this section with a short background on the CSIR, to better understand the context in which the rating system was introduced.

In the early 20th century, the Royal Society of South Africa sought the government's help to institutionalize the public funding of research [LM16, p. 2]. The evolution of the national funding bodies from 1911 is summarized in Table 1. Between the two world wars, there was a high level of dissatisfaction with the status of research in SA, which centered around the lack of coordinated research activities and lack of collaboration among researchers [LM16, p. 4]. This led to the establishment of the CSIR in 1945. The CSIR aimed to coordinate scientific research in SA, in particular, to support university scholarship and to place research in industries and national research laboratories in close contact with the universities. Despite its initial success, the CSIR was later affected by the increasing international isolation brought on by apartheid. The country was losing highly trained citizens who emigrated elsewhere and had difficulties in luring scientists from abroad [Kri07, p. 10]. The leadership of CSIR identified an issue which became central to the rating system: developing and monitoring skilled high-level researchers. They co-opted Jack de Wet to put the matter of national research funding on a more sound footing [Kri07, pp. 8–10].

With de Wet's involvement, the academic rating system was introduced. The underlying principle of the system[16] is identifying good researchers as the most important element of good research, and supporting them so that they could pursue any area they choose. The quality of the researcher is validated through exposure to peer review.

The academic rating system was designed to determine the level of funding awarded to a researcher. The system

Year	Administered by
1911–1917	Royal Society of South Africa
1918–1938	Research Grant Board
1938–1945	National Research Board
1945–1999	Council for Scientific and Industrial Research (CSIR)
1999–present	National Research Foundation (NRF)

Table 1. Evolution of the national funding bodies.

was introduced in the document entitled "A new look at the role of the RGD in the promotion of research in the South African universities" that was sent to research-active universities on April 8, 1983. These were primarily White universities: Universities of Cape Town, Free State, Natal, Port Elizabeth, Pretoria, Witwatersrand, Rhodes, Potchefstroom, Stellenbosch, and Rand Afrikaans. Notably excluded were the ethnic universities: Universities of Fort Hare, Durban-Westville, and Western Cape.

In this document, de Wet outlined his philosophy that the greatest single resource lay in the hands of the universities themselves: in the funds they possessed for the provision of staff, space, and basic equipment. A large proportion of academic staff did precious little research, while those who intended to pursue their scholarship lacked the necessary support and were often overburdened with non-research duties. Thus, research support should be based on identifying good researchers. de Wet reiterated his idea[17] by making a case for government support for infrastructure and funds to individual scientists. The latter support should be based on peer-reviewed evaluation of the researchers since the existing research formula which relied on publication counts was far too coarse a measure.

In May and June of 1983, de Wet and Reinhard Arndt visited western Europe, the USA, and Canada to investigate university research funding systems. They argued that the rating system could only work if the benchmark was international and not local [Mok20]. These visits resulted in a framework for the promotion of research in the universities, while also integrating the research effort between the CSIR and the universities. Four types of research activities were identified: **free research**, which should be funded without reference to the subject matter and researchers could work in any field they chose; **stimulated research**, which promotes a new field; **goal oriented research**, which has an additional objective, such as a better

[15] *This issue was highlighted in a report of an international panel commissioned to review mathematics research in SA in 2008/09, available on the NRF website.*

[16] *The historical accounts on the rating system in this subsection are summarised from* [Vau15, Chapter 3].

[17] *In a separate document entitled "A view on funding of research at universities" (title translated from Afrikaans), May 1, 1983.*

understanding of a problem area of national concern; and **commissioned research**, which would be done on a contractual basis.

The initial rating system required each candidate to submit a curriculum vita with a detailed list of publications, a statement of accomplished research with self-assessment, identification of the most significant papers, details of postgraduate students trained, and nominated referees. Research is then evaluated annually by a peer-review process conducted by a subject-specific committee that solicits reference reports from referees, 50% of which are nominated by the applicant and the rest independently chosen by the panel. This evaluation determined into which of the following categories a researcher would fall:

A: Leading international researchers
B: Internationally acclaimed researchers
C: Established researchers
P: Prestigious researchers (these are young researchers that have the potential to become international leaders)
Y: Promising young researchers

The funding package associated with ratings A and B would give researchers enough support for a period of five years.[18] This included a quota of research studentships at the Masters and doctoral levels. Those with C ratings would receive "basic support" for studentships plus funds for short-term assistance. The support packages would be for five years with a possibility for renewal subject to a thorough and strict review of what had been achieved. A solid component of training quality graduate students in research was an integrated and essential component of all this activity.

A comparison of the SA rating system with a similar system in Mexico is given in "Review of NRF Evaluation and Rating System."[19] It is reported that the Mexican system is implemented to encourage their scientists to remain in the country through salary augmentation. Thus, one may conclude that the SA rating system is unique.

4. Rating SA Mathematicians

The characteristics of the rating process are similar to the "generic" features for the evaluation of individual researchers endorsed by the International Mathematical Union General Assembly in August 10, 2014, entitled "Recommendation on the evaluation of individual researchers in the mathematical sciences."[20] In particular, the specialist committee for the mathematical sciences puts a strong emphasis on the evaluation letters[21] solicited from referees who are assumed to have an intimate knowledge of the work and the research field of the applicants. Specialist committees are required to select "an appropriate mix of national and international reviewers…for an A nomination there should **only** [own emphasis] be international reviewers…."[22]

Information on all successful candidates is publicly available on the website of the National Research Foundation (NRF) of South Africa. Most of our observations are drawn from an analysis of this data, as well as additional data that was requested from the NRF and the Department of Higher Education and Training. We have also obtained additional information from three databases: the American Mathematical Society's MathSciNet, Scopus, and Web of Science, especially the institutional affiliation of researchers from which one could draw some conclusions about emigration/immigration and joint appointments.

Research activities before 1984. We present a brief overview of mathematics research in SA up to the year of the introduction of the rating system. This has been deduced from examining data from MathSciNet, Scopus, and Web of Science, as well as private communications with people who were active in research in the 1980s. There are no articles in any of these databases for ethnic universities and technikons. In the 1960s, the staff members at ethnic universities were predominantly White, many with no PhDs. By 1984, there were no more than ten Black SA mathematicians who had completed their PhD at any SA university.[23] The research-active mathematicians were based mainly at the White universities, predominantly at the English-medium universities[24] and at the CSIR.

The CSIR created an in-house National Research Institute for Mathematical Sciences[25] (NRIMS) in 1961.[26] The mathematics research in the CSIR was predominantly applied in nature: numerical analysis, optimization, computation, applied statistics, and control theory. It was in support of projects focused around armaments, energy, and mining. However, there were mathematicians conducting research in areas of pure mathematics, namely, operator theory, approximation theory, and algebra. At

[18] *In present day, the rating is valid for six years.*
[19] *Report is available at:* `https://www.nrf.ac.za/information-resources/review-reports`.
[20] *See:* `https://www.mathunion.org/fileadmin/CEIC/ICM_2014_panels/Evaluation_of_individuals__FINAL.pdf`
[21] *From private communications with past and current chairpersons of the specialist committee for mathematical sciences.*
[22] *Full details available at* `https://www.nrf.ac.za/document/14-guidelines-selection-reviewers`
[23] *Job reservation legislation meant that none could be employed as academics or researchers at the White institutions or CSIR without a special permit. Such a permit was almost impossible to obtain.*
[24] *Universities of Natal, Witwatersrand, Cape Town, Rhodes.*
[25] *In 1986/7, NRIMS was incorporated into the Centre for Advanced Computing and Decision Support of the CSIR. See: P. Maritz, The South African Mathematical Society 1957–2007,* `http://www.sams.ac.za/history-sams`.
[26] *Further details in* [Kin90, pp. 147–149].

the universities, some of the research in applied mathematics was in collaboration with CSIR scientists within the same themes. Areas of activity in pure mathematics included topology (general, categorical, and algebraic topology), algebra (group theory, associative rings and algebras), functional analysis and operator theory, differential equations, and statistics. Despite the academic boycott, international academics, mainly from the USA, the UK, Israel, Canada, and Australia, continued to collaborate with SA mathematicians, visiting the White universities or as distinguished guests of the South African Mathematical Society.[27]

Patterns of research production. We highlight some patterns of research productivity in SA over the last three decades. Some of these are not uncommon in other science systems, others can better be understood from the socio-political perspectives summarized briefly in the previous sections. The overall population of SA is estimated to be just under 60 million, based on projections of the latest data from the United Nation. Of these about 51% are female, 9% White and 80% of African descent; in particular Black women constitute around 46% of the population.

Since its inception, there have been 28[28] mathematicians who have been awarded an A-rating. Only two of them are women: one works in graph theory and emigrated to Canada; and the other works in mathematics education and is the past president of the International Commission for Mathematics Instruction. The areas of research which have produced more than one A-rated researcher are topology, combinatorics, mathematical physics, and mathematics in science and technology.[29] International exposure appears to be a major factor in obtaining an A-rating. The majority of the A-rated scientists are either immigrants or are SA-born but spent time overseas as graduate students or during the early years of their careers. Among mathematicians of African ancestry, only one has attained an A-rating and there have never been any who are SA-born. Similarly, no mathematicians formerly classified as Coloured have earned an A-rating.

In terms of the "descriptors" of the rating system, researchers in the A and B categories enjoy "considerable international recognition" and this is further described as "researchers that have recently produced research that is internationally excellent in terms of originality, significance and rigour and which substantially advances knowledge and understanding in the field."[30] Some of the indicators mentioned in the document specifically for mathematicians refer to someone who has been "invited as a plenary speaker at international conferences and workshops; is regularly invited for research visits or lectures at overseas universities." It would be safe to predict that a tenured professor at a North American university, or someone at the level of a senior lecturer at a UK university, would be successful in gaining at least a C-rating under this system, possibly a B-rating.

A- and B-rated mathematicians are the top researchers in SA and currently constitute slightly over 10% of mathematicians working within the national science system (including science councils). The total number of rated mathematicians constitute just over a third of the mathematics workforce. Over 70% of the A- and B-rated mathematicians are currently concentrated at four of the 26 SA universities: two formerly English-medium universities and two formerly Afrikaans-medium universities. Since 1984, no more than ten women have earned either an A- or B-rating: three in graph theory, two in mathematics education, and one each in approximation theory, statistics, mathematical physics, and computer science. There is only one SA-born female of African ancestry ever to appear in this list.

We note that women and people of African ancestry are grossly underrepresented in the list of researchers who have ever earned a rating. In the first ten years of the rating system, only two male researchers of African ancestry were successful. Only ten females of non-European ancestry have ever received ratings, seven of whom are foreign-born. The formerly ethnic universities have had very few rated mathematicians, in many cases no more than five and most were educated at other universities. There is only one (formerly) ethnic university with a B-rated researcher.

Trends in collaborations with researchers in other countries have changed considerably since the introduction of the rating system. Prior to 1984, SA mathematicians were isolated due to the academic boycott. The rating system provided generous funding packages for top-rated researchers with no restriction on research projects to undertake. They received financial resources for postdoctoral fellowships, hosting research visitors, and undertaking overseas research visits. After the first democratic elections in 1994, countries in the developing world that had observed the academic boycott (e.g., India and other African countries) established ties with the new government of SA including academic exchanges. These factors enabled SA mathematicians to work with researchers from countries in the Middle East, Asia, and South America, which

[27] *See: P. Maritz, The South African Mathematical Society 1957–2007,* `http://www.sams.ac.za/history-sams`*, Part G: Programs of SAMS.*

[28] *One A-rated mathematician, who was awarded the rating in 1989, is from the University of Delaware and appears to have no connection to an SA institution.*

[29] *Here we are using the terms used for some ICM sessions.*

[30] *Full description in "Considerable International Recognition (CIR): A Guide for NRF Specialist Committees and Assessment Panels,"* `https://www.nrf.ac.za/document/12-considerable-international-recognition`.

previously had no links to SA. The top ten countries whose citizens have coauthored publications with SA mathematicians are the USA, Germany, China, Canada, Saudi Arabia, Austria, the UK, France, Pakistan, and Mexico.

The areas of SA mathematics research have been deduced from the self-description of research specializations that rated researchers have provided, as reflected on the website of the NRF. These are broadly:[31] combinatorics, ordinary and partial differential equations, mathematical physics (relativity, gravitational theory, quantum theory, string theory), operator theory and functional analysis, probability theory, stochastic processes and statistics, numerical analysis, biology and other natural sciences, fluid mechanics, general topology, and number theory.

It is generally accepted in the mathematics communities that an invitation to speak at the International Congress of Mathematicians (ICM), either as a plenary speaker or an invited speaker at one of the sectional sessions, is a prestigious recognition and an affirmation of the high esteem in which one is held by one's peers globally. In its more than 100-year history, very few SA mathematicians have earned such accolades; the examples we could find were Jill Adler (Hyderabad, 2010), Batmanathan Dayanand Reddy[32] (Seoul, 2014), and Mamokgethi Phakeng (Rio de Janeiro, 2018) though she was unable to attend. In many instances, there are very few common themes between the specializations of SA mathematicians and the topics of the Scientific Programme for the ICMs. One example worth mentioning is the field of topology. Over the years in the ICMs, at least 14 mathematicians have received a Fields medal for their work connected to algebraic topology. Algebraic topology is not one of the specializations of SA topologists, who mainly work in point-free, categorical, and asymmetric topology. Since 2000, only 20 papers in algebraic topology are listed in MathSciNet with an SA (co)author. However, in areas such as mathematical physics[33] and combinatorics, it is surprising that no SA mathematicians have been featured as sessional speakers, let alone plenary speakers.

In 2007, the NRF and Higher Education South Africa[34] (HESA) constituted a joint Review Committee, chaired by the second author, to put forward some recommendations on the future of the rating system. The committee commissioned five reports on various aspects of the system, and one was "Mapping the Formal and Informal Use of the Rating System over time by various Institutions."[35] The report noted that some institutions used the rating system, among other things, for (a) strategic goals: increasing the number of rated researchers would be a strategic objective; (b) recruitment: using the NRF list of rated researchers for headhunting purposes; (c) human resources management: using the rating as a criterion for appointment, promotion, and retention, etc.

Among the 28 A-rated mathematicians, five emigrated and only two have moved internally from one SA institution to another after receiving the A-rating. By and large A-rated researchers have remained at the same institutions. At the B-category, there has been some movement, especially when people were approaching retirement age at their home institution or had officially retired.[36] However, one institution lost the bulk of its B-rated mathematicians to other universities in a short period of time due to internal institutional conflicts.

The next generation (under 40). There are a very low number of young mathematicians who have been successful in earning a rating. The 2018 data from the Higher Education Management Information System shows that around 40% (or just over 200) of the academics in mathematics at SA universities are 40 years old or younger. These are the future academics and intellectual leaders of these disciplines in the country. Only 39% of them have completed their doctoral degrees; 37% hold a Masters degree and the rest teach with the equivalent of a 4-year first degree. A PhD is an unofficial minimum requirement for an applicant to be considered for a rating. Overall, around 25% of all non-PhD holders teaching mathematics are currently pursuing their PhDs while still working full-time. Since it usually takes longer for people registered part time to complete their studies, they would, on average, be much older when they complete their doctoral degrees and unlikely to have had international exposure. They can ill afford time for focused uninterrupted postdoctoral research.

There have only been nine mathematicians who received the P-rating since 1984, five of them emigrated. The proportion of staff under 40 who have earned a rating by the NRF is just under 17%; in particular 23 in mathematics and only ten in statistics. These low numbers of NRF-rated young academics in mathematics is worrisome when one reads the descriptors of the rating categories. To put it differently, only 17% of young researchers are considered likely to become future international leaders in their field or are recognised as having the potential to establish

[31] *More granular information on the subdisciplines or topics of specialization are reflected on the NRF website.*

[32] *Both Adler and Reddy are A-rated.*

[33] *An A-rated mathematician is regarded as one of the leading theorists in cosmology and one of a handful of SA scientists to be made a Fellow of the Royal Society. He coauthored with Stephen Hawking the seminal text* The Large Scale Structure of Space-Time.

[34] *This is a voluntary association consisting of all the presidents of all the 26 universities in SA.*

[35] *Reports available at:* `https://www.nrf.ac.za/information-source-group/review-reports`.

[36] *There is no single retirement age at the different SA universities and some institutions retain A- and B-rated researchers beyond their official retirement age.*

themselves as researchers within a five-year period after evaluation. The demographic profile of under 40 mathematicians is 42% female and 58% male; 44.9% African, 8.3% Coloured, 10.7% Indian, and 36.1% White.

Observations made for the A- and B-rated mathematicians are replicated in this group. Firstly, they work in similar research areas. Secondly, none of the rated young mathematicians are based at the formerly ethnic universities or technikons, and not a single one of them is SA-born of African descent. The SA education system, from high school to university is not producing enough, if any, young mathematicians of African descent who have shown the potential, according to the rating system, to become future international leaders in their field or who are recognised as having the potential to establish themselves as researchers within a five-year period after evaluation. We are struggling to address and overcome the legacy of the Bantu Education.

Mathematics and the rating system. During the early years of the rating system, research funding was linked to a researcher's rating. These researchers were highly concentrated at the formerly White universities. Consequently, the formerly ethnic institutions received very little research funding from this source. Reinhard Arndt, head of the FRD, recognised that implementing the system in the apartheid higher education landscape would produce racially skewed outcomes. He developed another excellence-based scheme, the Development Programme for Black Universities, to accelerate the development of ethnic institutions and transform the racial demographics of students and the workforce in science, technology, and innovation [Mok20]. We are aware of only one university which chose mathematics as an institutional priority area under this scheme. The introduction of a new rating category specifically targeting "late entrants" enjoyed mixed success and yielded rather disappointing results.

Arndt, who was a firm believer in the Humboldt Principle of the union between teaching and research, also established the Technikon Development Programme [Mok20]. Although technikons did not have a research mandate, this programme challenged their academic staff to factor research into their mandates. The rating system has transformed the higher education system in SA, as research intensified in the universities. Some SA universities have fairly high ratings when benchmarked against the rest of the world [Mok20].

Highly rated researchers received financial support to attract and host research visitors and postdoctoral fellows. This led to some diversification of research areas, one often-cited example being the theory of locales in topology. Some of the young researchers are foreigners who came as postdoctoral fellows and stayed on as full-time staff, and are among those who have been successful in gaining a Y-rating and subsequently moving on to the higher rating categories.

The impact of the NRF rating system was examined in one of the five (joint HESA/NRF) reports.[37] As expected, the committee reported that a significantly large proportion of publications involving rated researchers were in co-authorship with international researchers—this was not the case for non-rated researchers. It was also reported that researchers preferred to publish in journals indexed by the Web of Science compared to local journals. Furthermore, the average per capita publication rates were significantly higher for rated researchers when compared to non-rated researchers.

In the 2010s, research funding was gradually delinked from ratings. However, the NRF often gave preference to rated researchers in its other funding instruments. An example of this was the South African Research Chairs Initiative established in 2006/07 and aimed at "increas[ing] the number of world-class researchers in South Africa." The first quinquennial review[38] of the programme reported that 81% of the Chairs were male, 63% were White, and 31.5% had been allocated to researchers who were immigrants. The latter were expected to apply for ratings after taking up the position. Currently, research funding is a mix of limited unencumbered grants for rated researchers and project-based funding aligned to South Africa's national priorities.[39]

Since researchers have to be re-evaluated every six years, and their rating is based on the previous eight years, there is a view that the rating system discourages researchers from venturing into new areas of research lest their productivity drop [Vau15, p. 123]. This could be one of many plausible explanations for the remark made by the International Panel for the Review of Mathematical Sciences Research in South Africa which states that "*In mathematical sciences, research is not fully distributed across different areas of mathematics. In particular, there are some contemporary, mainstream sub-fields that are not represented and some research in SA is disconnected from areas of contemporary interest.*"[40]

There is, arguably, a potential limitation of the system as it favors a narrow disciplinary focus. The requirement of a "coherent stream of research" has been widely interpreted to suggest that an applicant's research should fall into a largely monodisciplinary stream of research. Denying a researcher a rating because of changes in trajectory

[37] *Reports available at:* `https://www.nrf.ac.za/information-source-group/review-reports`.

[38] *Review available at:* `https://www.nrf.ac.za/division/rcce/instruments/research-chairs`.

[39] *For details, see:* `https://www.nrf.ac.za/funding`.

[40] *Report available at:* `https://www.nrf.ac.za/information-source-group/review-reports`.

(interpreted as a lack of coherent focus) could potentially count as harmful practice, as it can incentivise a lack of innovation and constrain natural changes in the trajectory of an individual's research interests [Cal18, p. 2]. There is also a view that this requirement creates an incentive to apply for evaluation in very narrowly focused areas in order to maximize the rank that the researcher achieves. This creates an ambiguity in the comparison of ratings, since the wider scholarly significance of very narrowly defined research areas is not always clear [Fed12, p. 9]. There has also been evidence that the system does not put much value in research outputs generated by multiple authors. Thus, researchers who tend to collaborate with others face greater challenges in achieving higher ratings than researchers who work on their own [Fed12, p. 18]. In the long run, would it be likely that researchers avoid collaboration in order to obtain a higher rating? As we learned in Section 3, lack of collaboration had led to unsatisfactory research in the early days of research in SA. All of these factors may harm the future of mathematics research in SA.

5. Conclusion

This article provides a snapshot of the SA mathematics research landscape and an examination of it through the prism of the rating system. We conclude with a few observations about the rating system and its impact on the SA mathematics research landscape. First, the rating system was introduced to provide, among other aims, a benchmark of the international standing and recognition of SA researchers. Since no other countries have adopted a similar system,[41] some reviews of the rating system have raised key questions about a common interpretation and acceptance of the descriptors, especially for the A- and B-categories. The mathematicians in these categories constitute the top decile within the SA science system. The question would be whether these researchers are rated (or are recognized as being) the top decile in the world. To recall Fedderke's point: *"the wider scholarly significance of very narrowly defined research areas is not always clear."*

Second, the list of all rated scientists constitute "research-active" faculty within the SA sciences system. We observe that only 35% of academics in SA mathematics are rated by the system. It means that SA does not have even half of its mathematicians currently classified as active in research. This is very low by international standards, as in many countries one cannot get tenure without being "research-active." It should however be noted that some researchers, although active and possibly well-respected, allow their rating to lapse for a variety of reasons, e.g., they may have branched into new areas of specializations.

[41] *Note the fundamental difference to the Mexican system.*

Third, the research strengths of SA mathematicians are deduced from the NRF's data.[42] This is useful information for prospective PhD students looking for potential supervisors, especially given the fact that SA is a destination for postgraduate studies for students from other African countries. We note the disconnect between the research specializations of SA mathematicians from areas of contemporary interest.[43] This may have been caused by the system itself which favors a narrow disciplinary focus, and hence discourages SA mathematicians from venturing into new areas of research. The system seems to also favor single-authored publications, which one may interpret as discouraging collaboration. One may argue that these two factors, in the long run, may bring back academic isolation. Another conclusion that may be drawn here is that there seems to be a circular nature in how the rating system has influenced the way research is conducted. Researchers may shape their research with the intention of fulfilling the criteria for rating, instead of pursuing their own research agenda, as intended by de Wet.

Fourth, we observe that most rated mathematicians are at only four or five historically White universities, and they are predominantly male and White. Research activities, including research training, is mainly concentrated at these universities. They graduate the bulk of postgraduate students with international linkages and collaborations. Over the years the links between ratings and research funding has varied but, be that as it may, it has led to a concentration of research funding allocated by the NRF at these historically privileged institutions and therefore has contributed to perpetuating inequities, which can be traced back to apartheid policies.

Fifth, we note that the highly rated researchers, especially those in the A-category, are either immigrants from other countries or SA citizens trained abroad or having had international exposure in the early years of their careers. Among the rated, early-career researchers, there is a sizeable proportion who have either held a postdoctoral position or have been trained outside of SA. This raises the question about the ability of SA's university system to produce significant numbers of world-class mathematicians. We cannot determine whether this is a reflection of the postgraduate training in SA and postdoctoral opportunities available for those that follow an academic career, or the process inadvertently favors researchers with an international experience, or both.

Sixth, we highlight the race and gender inequities reflected in the low numbers of women and Black

[42] *Rated mathematicians provided their areas of specializations on the NRF website.*

[43] *As mentioned in Section 3, this issue was highlighted in the review report by an International Panel appointed by the NRF in 2008/9.*

mathematics researchers among the rated mathematicians. Black people and women are shockingly underrepresented in the higher categories of this system. One could argue that the gender disparities associated with the SA rating system are an example of similar trends globally and consistent with the findings in the book *A Global Approach to Gender Gap in Mathematical, Computing and the Natural Sciences*.[44] One could also argue that racial disparities are not unique to SA, if one were to examine other science systems blighted by a history of slavery and/or colonialism. Intersectionality of race and gender is one framework for examining the gross underrepresentation of Black women in the rating system in general and their near absence in the top categories in particular. If one is Black, female, and working at a historically Black university, the prospects of a rating have been and continue to be almost non-existent. There were special interventions that appear to have had very limited success and brought about negligible change.

It is unlikely that any changes to the rating system will take place unless such a recommendation comes through an independent review of the NRF. A meritocratic system like the rating system implemented in a highly unequal country like SA is likely to perpetuate or even exacerbate inequities. With a population which is at least 90% Black and 51% female, SA has developed an evaluation system or a benchmarking tool whose outcomes both reflect and expose the long-term consequences of Hendrik Verwoerd's earlier quote "*what is the use of teaching a Bantu child mathematics?*" Looking more broadly, however, this article aims to call attention to and provide an understanding of the rating system in the context of both the history, and the future, of SA. It serves as a first attempt to help chart a new course for SA mathematics.

ACKNOWLEDGMENTS. The authors would like to thank the anonymous referees and the editors for their valuable suggestions on this article.

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Credits

Author photos are courtesy of the authors.

[44] *C. Guillopé and M.-F. Roy, A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to Measure It, How to Reduce It?, International Mathematical Union, 2020.*