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Growth of the chemistry discipline over the last 120 years, as documented by the *SAJS*

Significance:

This article demonstrates how *SAJS* has played a significant role in validating and documenting scientific breakthroughs in chemistry, among other disciplines. As a central discipline, chemistry has contributed to economic and industrial growth in manufacturing, mining, health, food, water, energy and other industry sectors. The discipline supports the implementation of nearly 12 of the 17 United Nation's Sustainable Development Goals 2030. Chemistry, through research and innovation, will continue to play a significant role in responding to emerging technologies that drive industrial revolution, with artificial intelligence as one of the enablers.

Introduction

The economic and industrial development of South Africa has relied on science, technology and innovation advancement, as informed by research. In the last 120 years, the *South African Journal of Science* (*SAJS*) has provided researchers in most disciplines, including the chemistry field, a platform to disseminate their findings, share discoveries, and contribute to the collective body of knowledge. Chemistry is a central discipline that underpins the physical, material, and biological world, and it finds application across multiple fields, including manufacturing, mining, health, food, water, energy, and other industrial processes. In a formal sense, chemistry is traditionally divided into five major sub-disciplines: organic, biochemistry, inorganic, analytical, and physical. However, it is projected that chemistry will continue to grow into a multidisciplinary field, resonating with the Journal's scope. We note that a significant contribution to South Africa's industrial processes involves chemical research. In this article, we discuss the historical perspectives of *SAJS* and its contribution to the growth of the chemistry discipline and how this growth has impacted the industrial, socio-economic and environmental sustainability of the country. The key aspects covered in this article include the growth of the chemical industry in South Africa since 1900, and the role of chemistry in achieving the Sustainable Development Goals (SDGs). Other aspects include the contribution of the discipline to emerging technologies, including their interplay with artificial intelligence to drive the Industrial Revolution.

Historical perspectives: The role of *SAJS* in promoting chemistry

SAJS publishes studies in life sciences, social sciences, physical sciences and technology. It covers a wide range of cross-cutting topical issues, including research ethics, social media, academic integrity, theology, burden of disease, and higher education, as well as water, energy and climate change, among other issues. The Journal archive runs from Volume 1 Issue 1 January 1905 to the most recent issue, 120 Issue 9/10 September 2024.[1] The Journal was established in 1903 as a Proceedings of the Annual Meetings of the South African Association for the Advancement of Science (S_2A_3).[1]

One of the first articles in *SAJS,* authored by Cunningham in 1905[2] and entitled 'Unconscious Assumptions in Economics', discussed economic and industrial developmental issues affecting South Africa at that time. In another article by S. Kidd in 1905[2], entitled 'The study of economics in South Africa', the author underscores the importance of teaching the subject of economics at the bachelor's degree level. An article by Sutherland in 1905[3] entitled 'Some statistics of the mineral industry of the Transvaal' discussed industrial processes involving the output of gold, silver, coal and diamonds. These examples serve to illustrate the diversity of the subject fields covered by *SAJS*, based on the few selected publications in the early days of the Journal. Academic journals provide access to knowledge and act as vehicles for sharing research outcomes with the global scientific community. They provide researchers with a platform to disseminate their findings, share discoveries, and contribute to the collective body of knowledge.[4] The *SAJS* has therefore documented the country's evolution of scientific discoveries as well as the economic and Industrial Revolutions of the 20th and 21st centuries.[1]

We selected several publications of the Journal in the field of chemistry in the 20th century to highlight the growth of the discipline. 'Modern chemistry', authored by Green in 1919[5], discussed the concept of modern chemistry. The author commented on the broadness, enormity and complexity of the chemistry field "for a human mind to comprehend". Another article by Rose (1929)[6] entitled 'Alcohol mixtures as motor fuels in South Africa', discussed the use of alcohol as a liquid fuel to supplement petrol shortages or "abnormal rises in petrol price". A few other articles in chemistry that were published in the early 20th century include 'The occurrence of sodium nitrate in South-West Africa' by Thomas (1929)[7] and 'On the laboratory methods available for examination of the physical nature of soil: A discussion and selected reviews' by Coutts (1929)[8]. The latter is one of the few articles in the early years of the Journal's existence that reported a laboratory investigation of soil analysis, in which the procedures involved the determination of physical-chemical parameters following sample preparation and extraction of the target components. Coutts[8] demonstrated typical chemistry methodologies as we know them in present-day research.

The above examples of selected chemistry articles serve to highlight the importance of the chemistry discipline during South Africa's economic, environmental and industrial growth since the 20th century. However, we opine that the articles published in the early years of the Journal were very broad and shallow in content as the authors reported limited experimental methodological procedures compared to today's chemistry structure and methodology

as we know them. It is our opinion that the Journal has been instrumental in promoting the visibility and impact of the South African research community and that of the continent, in various sectors. As indicated above, *SAJS* is a "multidisciplinary journal on African-relevant issues of interest to readers in various disciplines and for the benefit of scholars, educators, policymakers and the general public"[1]. The Journal, through its publications, has documented the impact of the Industrial Revolutions[9] (IRs) from the 20th century to date. Historically, "South Africa's science has a long and proud tradition, born in the mid-18th century from the works of amateur natural historians and astronomers who travelled to the Cape Colony at that time, to satisfy their intellectual curiosity", as reported by Mouton and Gevers[10].

During the 21st century, the 4IR[11] has benefited tremendously from artificial intelligence (AI), which has seamlessly integrated itself into various sectors, enhancing efficiency, streamlining processes, and ultimately paving the way for a brighter future as we move to the 5IR. Ziatdinov et al.[12] indicated that the 5IR is a "transformational point in human history, where the harmonization of human and machine intelligence emerges as the imperative, for the advancement of humanity". Chemistry as a central science, no doubt, has contributed to the technological development that led to the Industrial Revolution, particularly advanced material chemistry research and innovations[13] which have led to products that have played a steering role in earlier Industrial Revolutions[14]. Chemical processes have played a significant role in South Africa, as reported by Majozi and Veldhuizen[15], in establishing industries such as oil refineries, mining, chemicals, manufacturing (paper, steel, plastic, glass, etc.), water and electricity. Furthermore, advanced material chemistry is currently a prominent enabler of the 4IR through developmental innovations such as "new smart materials (organic light-emitting diodes, optical fibres and carbon nanotubes), used in communication technology and nanochip technology", as reported by Malik et al.[16]

Growth of the chemical industry in South Africa since 1900

In South Africa, the main chemical industries include speciality chemicals, organic and inorganic chemicals, pharmaceuticals, polymers and rubbers, fine chemicals, plastics products, consumer chemicals, liquid fuels, and others. Both liquid fuels and plastic products contribute about 50% to the chemical industry, as reported by Majozi and Veldhuizen[15]. South Africa's industrial research and development has been closely linked to the establishment of the earlier three key organisations which are still part of the macro-industrial landscape, namely the Iron and Steel Corporation (Iscor, now Mittal Steel South Africa), the Electricity Supply Commission (Eskom) and the Industrial Development Corporation (IDC). The Council for Scientific and Industrial Research (CSIR), established in 1945, played a major role in promoting and carrying out cutting-edge scientific research, and, through its influence, ultimately ensured a wider appreciation of the developmental role of scientific research within the country.[10] Sasol, on the other hand, was established as a state-owned chemical and energy company known as the South African Coal, Oil and Gas Corporation in 1950 in Sasolburg[17], and produced chemicals and petrochemical products. *SAJS* has played a key role in documenting some of the scientific breakthroughs from industrial research in peer-reviewed articles, which remain the major vehicle by which research findings are validated and scientists obtain credit for their contributions.

Scientists in South Africa in the early 20th century made significant contributions to industrial chemical research. For example, Dr James Moir (1902–1925) played a major role as one of the pioneering chemists in the early 1900s.[18] Dr Moir was mainly an organic chemist but made a significant contribution in the field of inorganic chemistry. His research investigated gold extraction, employing products such as thiourea for removal of cyanide using ferrous sulfate. He investigated the 'Purple of Cassius', a purple pigment formed by the reaction of gold salts with tin(II) chloride. This chemical has been used to impart glass with a red colouration, as well as to determine the presence of gold as a chemical test. "Dr Moir was also a theoretical chemist who played a role in the development of atomic theory and made suggestions to help unravel the nature of the atom, the composition of the nucleus and chemical combination", as reported by Loyson[18].

The mining sector is one of the oldest industries in South Africa that has benefitted from chemical sciences research. According to the World Bank[19], mining has contributed significantly to South Africa's economic growth and employment, owing to its mineral resources, including the platinum group metals, gold, iron ore, and manganese. The mining sector has been a strong incentive for investing in research in the field of chemical sciences in South Africa, as reported by Mouton[20].

To demonstrate how chemical sciences have positively impacted South Africa's industrial and economic growth, we briefly discuss the contribution of Sasol and Eskom. The former produces synthetic fuels and chemicals as the core products. In addition, Sasol[17] serves various industries including agriculture, automotive and transport, building and construction, consumer goods, flavours and fragrances, health and wellness, home care, industrial and institutional cleaning, inorganic materials and catalysts, manufacturing and industrial, mining, oil and gas, paper and water, packaging, printing and coatings, personal care, polymers, textile and leather. "The fuel products, which include petrol, diesel, jet fuel, illuminating paraffin, fuel oil, bitumen and liquefied petroleum gas, contribute about 8.5% to South Africa's GDP and supplies around 18% of the country's primary energy", as reported by Johnson, the Business Development Executive of Adcorp BLU company.[21]

Another important industry in South Africa is that of coal[22] which provides the primary energy needs for electricity generation, petrochemicals and steel production. Chemistry processes are involved in the coal preparation and beneficiation using acids and bases to remove impurities. Coal is composed of nitrogen, oxygen, carbon (50–98%), ash (which contains silica, alumina, iron oxide, and calcium), sulfur, hydrogen (3–13%), water and particles of inorganic matter.[22]

Chemistry and the Sustainable Development Goals

The chemistry enterprise offers opportunities in technology, the economy, and human health, and there are many ways in which chemists are working to support global sustainable development. The American Chemical Society[23] has identified seven priority SDGs: #2 Zero Hunger, #3 Good Health & Well-Being, #6 Clean Water, #7 Affordable & Clean Energy, #9 Industry, Innovation & Infrastructure, #12 Responsible Consumption & Production, and #13 Climate Action. There are five additional SDGs[24] that are foundational to the work of the chemistry community. These are SDG #5 that supports gender equality by empowering all women and girls through chemical education and skills development, #10 reducing inequality by providing equal access to opportunities, #11 making cities and human settlements inclusive, safe, resilient and sustainable by producing quality building materials, #14 supporting conservation and use of the oceans, seas and marine resources for society's benefits, and #15 protecting and restoring use of terrestrial ecosystems.

To give an example of the applications of chemistry in the SDGs, we have looked at the analytical chemistry subdiscipline. This is a multidisciplinary branch of chemistry that cuts across many science disciplines. Oliveira[25] highlighted the applications of analytical chemistry, including quality control of food, emerging microplastics pollution, nanoparticle and single particle determination, the control and removal of toxic elements and substances from environmental systems (water, soil, and air), and all chemical hazards that societies are exposed to today, which need attention and control.

Chemistry and emerging technologies for the Industrial Revolution

The advancement of technologies during the First to Fourth Industrial Revolutions (1IR to 4IR)[9] has seen the emergence of new fields such as nanotechnology which draws significantly from material chemistry[13].

The emergence of 4IR was characterised by technological advances in different fields, including faster computer processing, big data analytics, artificial intelligence (AI), robotics, 3D printing, blockchain, nanotechnology, biotechnology, Internet of Things (IoT), virtual reality (VR) and augmented reality (AR), etc.[26]

In this section, we have chosen nanotechnology and nanoscience as an example to illustrate the role that chemistry has played in the Industrial Revolution. We note that nanotechnology is listed as one of the enablers of 4IR as reported by Mouton[20]. Nanotechnology is the science of designing, producing, and applying structures and devices having one or more dimensions of about 1–100 nanometres.[27] This field has allowed interactions and collaboration with other disciplines such as engineering and medicine. Applications of nanochemistry include medicine, cosmetics, sensors, catalysis, textiles, automotive industry, structure and engineering, defence and medical applications such as magnetic resonance imaging detection (MDR), drug delivery, tissue engineering, enzyme reactions, nanowire compositions, energy, and water treatment, among other sectors.[27] We chose to discuss nanotechnology as an example, to highlight the role of emerging fields in shaping the direction of academic disciplines.

In our opinion, nanotechnology has contributed to the multidisciplinarity of the chemistry discipline in which a significant number of researchers (including the authors of this article) in chemical, biological, physics and engineering sciences in South African universities and research centres are publishing.

Chemistry research themes in South African institutions

Scientists from universities and research institutions in South Africa are the main contributors to *SAJS* publications. Our brief survey of *SAJS* publications shows that researchers in chemical sciences in most of the South African institutions of higher education are publishing authoritative research on all branches of chemistry, including organic, inorganic, solid-state, catalysis, analytical, physical, material science, nanoscience, and chemistry education. This section reports a brief survey of selected universities in South Africa, to highlight the teaching and research areas conducted by the chemical sciences departments. In our opinion, publications in *SAJS,* to some extent, reflect the teaching and research thematic areas in universities and research institutions. It is for this reason that we found it necessary to do a brief survey of teaching and research thematic areas in chemistry in selected universities in South Africa, to highlight the interlink between teaching and research, and publications in *SAJS* in the chemistry discipline.

In order to establish the thematic areas of teaching and research in South African universities, we selected a few universities: the Universities of Johannesburg[28], Witwatersrand[29], Cape Town[30], Stellenbosch[31], KwaZulu-Natal[32], Pretoria[33], Venda[34], Zululand[35] and Walter Sisulu[36]. We visited their websites to determine their teaching and research themes. We established that some of these universities offer teaching courses in traditional areas of chemistry, namely, analytical, inorganic, organic and physical chemistry. In some of the universities, the teaching courses were broad and included special topics that mirrored the research themes. Generally, the spread of research programmes differs significantly between universities.

As indicated in the previous section, *SAJS* publishes work from South African researchers as well as from outside the country, mainly from the continent[37] as well as chemistry publications authored by researchers from non-chemistry departments[38]. A spot-check of some articles shows collaborative and multidisciplinary research in health sciences, biotechnology and engineering fields.[39] Applied research is also evident from some of the publications in the medical field, energy, waste management, and climate issues, to mention a few.[40]

Conclusions: The future of the chemistry discipline

The *SAJS* has contributed to science development in South Africa by documenting the country's evolution of scientific discoveries, as well as the economic and Industrial Revolutions through the 20th and 21st centuries. The Journal has promoted the growth of the chemistry discipline by disseminating findings by researchers from different institutions, which have played a significant role in the country's industrial processes. The chemistry discipline, as we know it today, has shown growth since the 17th and 18th centuries when the subject field was at alchemy level.[41] In this paper, we have presented historical perspectives of the Journal by highlighting how the chemical industry in South Africa has grown since 1900. Chemistry has contributed to emerging technologies and Industrial Revolutions, as well as the implementation of SDGs.

We opine that *SAJS* will not only continue to play the fundamental role of a repository of science knowledge but also the critical review process which has influenced the increasing complexity and the multidisciplinarity of research fields including chemistry, so as to meet the demands of our global scientific community.

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Declarations

J.C.N. is on the *SAJS* Editorial Advisory Board. There are no competing interests to declare. There is no AI or LLM use to declare. Both authors read and approved the final version.

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