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# Science Centres, STI and the Fourth Industrial Revolution

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## Abstract

When considering the technical and systemic concerns of the sustainability of science centres as agents for science awareness, communication, engagement and education that are at the forefront of Fourth Industrial Revolution (4IR), the impact of science centres on the National System of Innovation (NSI) interventions should certainly be measured empirically, through monitoring, evaluation, and review mechanisms. This paper argues that science centres have a key role to play in Science, Technology and Innovative (STI) imperatives as well the Fourth Industrial Revolution (4IR). To this end, the South African Framework for the Promotion of Excellence in a National Network of Science Centres (2005) is evaluated. Moreover, the positioning and role of science centres in this landscape is examined, in terms of science awareness, communication, engagement and education. The case study of the Sci-Bono Discovery Centre - the largest science centre in the Southern Hemisphere - will be utilised to further understand the role of science centres in the NSI, STI and the 4IR.

***Keywords:*** science centres; policy; STI; 4IR; Sci-Bono Discovery Centre

## Introduction

Science Centres have been increasingly recognised as important venues for promoting science, technology, engineering, and mathematics (STEM) education. This paper departs from two assumptions related to the 2023 conference theme of the Southern African Association of Science and Technology Centres (SAASTEC), "Futuristic Science Engagement." The assumptions relate to the scope of contributions and discourse on the role and activities of science centres in tangible scientific initiatives and projects. Firstly, concerning discourse on the subthemes of science centres at the forefront of 4IR, science centre sustainability, collaboration, twinning and sharing, and measurement of the overall impact, rich, rigorous and empirically sound contributions were shared. Secondly, given that the community of science centres in South Africa has proven to be a valuable resource for government, the formal and informal education landscape, and a legitimate stakeholder in the global scientific community, contributions evidenced cutting-edge best practices.

This paper hopes to synthesise the positioning and role of science centres in South Africa. The paper discusses science centres and policy, particularly the Framework for the Promotion of Excellence in a National Network of Science Centres (2005) in the first section. In the second section the discussion will focus on the role of science centres in the NSI and STI, particularly with regard to science awareness, communication, engagement and education. The third section will employ the case study of the Sci-Bono Discovery Centre, the largest science centre in the Southern Hemisphere, and its role in STI and ICT. The fourth section will continue the case study of the Sci-Bono Discovery Centre, and its inroads into the Fourth Industrial Revolution.

### *Science Centres and Policy: Framework for the Promotion of Excellence in a National Network of Science Centres (2005)*

The Framework for the Promotion of Excellence in a National Network of Science Centres (2005) is the only high-level policy document that concerns Science Centres in South Africa. It is rather dated, formulated during the period when Derek Hanekom was the erstwhile Minister of the Department of Science and Technology (DST). However, it is still significant as it charted the path for the accreditation of Science Centres, which is still applied to date. South Africa now has 35 Science Centres, and as members of the Southern African Association for Science and Technology Centres (SAASTEC) and the South African Agency for Science and Technology Advancement (SAASTA), respectively, they play a critical role in communicating Science, Technology, Engineering, and Mathematics (STEM), together with the "A" for "Arts" component, which has in recent years given rise to the more comprehensive acronym "STEAM".

The document defines a science centre as: "a permanently established educational facility that offers an informal educational experience in STEM through interactive exhibits and/or displays and/or interactive programmes" (DST, 2005, p. 4). In addition, it asserts that "the underpinning principle for this framework is to design and implement a developmental approach that will support continuous improvement rather than compliance with minimum requirements" (DST, 2005, p. 5). According to the Minister's Foreword, "in 2005, the Department of Science and Technology, together with the local science centre community, therefore formulated four strategic focus areas through which science centres in South Africa respond to the needs of the local communities, namely, the promotion of science awareness among learners and the general public; contributing to the learning and teaching of mathematics, science and technology; the promotion of science, engineering and technology careers; and contributing to the identification and nurturing learners with talent and potential" (DST, 2005). As such, the stated objectives of science centres were with respect to science awareness, learning and teaching of STEM, promoting STEM careers, and nurturing learner talent. To this end, science centres were tasked with defining and developing programmes, and they had to adhere to value-based corporate governance, given that they would receive significant external funding from the public and private sectors. The framework was also intended to establish customised development programmes for each centre to promote diversity in its offerings.

At the time, the Department of Science and Technology (DST) was governed by the first White Paper on Science and Technology (1996), which sought to build a healthy NSI that advances the country's social and economic development priorities. It was found that in order to do so, society in general should understand science, engineering and technology (SET) and its critical role in ensuring national prosperity and a sustainable environment. The 1996 White Paper advocated "a two-tier campaign to promote awareness and understanding of SET, namely, (a) promoting science and technology literacy, and (b) promoting awareness of the power of science and technology" (DST, 2005, p. 2). In other words, fostering an understanding of science and technology and their instrumental value for society informs the role of science centres, focused on both the youth and the general public. Furthermore, science centre programmes were envisaged to complement formal teaching and learning of mathematics and science, which are critical in developing SET human capital, which in turn enables the building of a healthy NSI. Overall, the accompanying "National Norms and Standards for a Network of Science Centres in South Africa" policy articulates the following four goals for science centres in South Africa: a) To promote science and technology literacy among young people and the general public; b) To contribute to the enhancement of learner participation and performance in science, technology engineering and mathematics (STEM); c) To identify and nurture youth talent and potential in STEM; d) To provide career education in STEM-based disciplines (DST, 2005, p. 2).

The science centre policy feeds into the South African Ten-Year Innovation Plan (TYIP) (2008-2018) objectives to inculcate innovation as a national competence, human capital development and knowledge generation at the level of the youth and general public, as opposed to only government and business. In terms of the Framework for the Science Technology and Innovation Decadal Plan (2019) that addresses Africa's Sustainable Development Goals and advances transformative change; unlike Schot and Steinmueller's (2016) framing, which has macro implications. The "Three Framings of Innovation Policy" by Schot and Steinmueller (2016) was employed as a heuristic tool to analyse and understand the necessary transition to new policies. Specifically, the argument by Schot and Steinmueller (2016) was adopted, holding that there are two established frames in contemporary innovation policy discussions. The first is the "institutionalisation of government support for science and R&D with the presumption that this [will] contribute to growth and

address market failure in private provision of new knowledge" (DSI, 2019a, p. 4), which was adopted globally after World War II. The second frame, as per the authors, emerged in the 1980s in the context of globalisation and the need for competitiveness. The proposed approach was that STI policy should focus on building a national system of innovation "through links, clusters and networks, and on stimulating learning between elements in the systems, and enabling entrepreneurship" (DSI, 2019a, p. 4).

In addition, Schot and Steinmueller argue that the third framing is "linked to contemporary social and environmental challenges such as the Sustainable Development Goals (SDGs)" and "transformative change" (DSI, 2019a, p. 4). In this sense, transformation refers to prioritising "socio-technical system change as conceptualised in the sustainability transitions literature." Furthermore, Schot and Steinmueller (DST, 2019a, p. 4) argue that "transformative change framing involves questioning how to use science and technology policy to meet social needs and [to] address the issues of sustainable and inclusive societies at a more fundamental level than previous framings or their associated ideologies and practices." As such, the transformative frame focuses on experimentation and the argument that the Global South does not need to play catch-up to follow the transformation model of the Global North (DST, 2019a, p. 4). However, the authors concede that the transformative change framing does not necessarily replace the other two previous framings, as it is still underdeveloped. Nonetheless, the three framings tend to compete as frameworks formulated by policymakers, depending on their interpretation and understanding of the framings.

Science centres, instead take a grassroots, rather than macro approach that goes directly to foundational education of youth and informal education of the general public. This is the proposed approach where STI policy focuses on building a national system of innovation "through links, clusters and networks, and on stimulating learning between elements in the systems, and enabling entrepreneurship" (DST, 2019a, p. 4). In this respect, the relevant networks are those of science centres throughout the country. The science centres' policy speaks to the White Paper on Science, Technology and Innovation Science (2019b), in terms of its intent to grow the role of science, technology and innovation in a more prosperous and inclusive society. Finally, the Decadal Plan's (2022-2032) guiding values of inclusivity, excellence, sustainability and entrepreneurship, which are in turn based on the principles of transformation, developmental responsiveness, partnering and efficiency, are tackled at a foundational and grassroots level by science centres that reach youth and the general public through awareness and communication of STI, STEM and STEAM.

### *The Role of Science Centres*

Science Centres are aimed at science awareness, science communication, science engagement and science education, through a variety of activities and special events. It is thus important to ascertain how science centres or museums and academia engage with the public in order to promote STI in the field of public engagement with science.

### *Science Awareness*

Regarding science awareness, according to the National Research Fund (NRF) there is a long-term commitment to strengthen the relationship between science and society. To this end, the latest White Paper on Science, Technology and Innovation (2019) introduces a policy shift that allows for greater collaboration with civil society in Science, Technology and Innovation (STI). The goal is to build a culture of innovation throughout society by making citizens aware of the value and threats of science, and how it could be used in daily life.

Hannan, Reddy and Juan (2016) in their report *Science Engagement Framework and Youth into Science Strategy: Science Awareness Spaces in South Africa* (March 2016) engage the role of science spaces which foster non-formal and informal learning. They advocate a life-long process of learning that provides opportunities outside the formal classroom for both children and adults, in order to "satisfy intellectual curiosity, provide relaxation and enjoyment and to facilitate the gaining of knowledge" (Hannan et al., 2016: 2).

More specific to science and discovery centres, Hannan et al., highlight that there are 34 science centres in South Africa that "play an important role in exposing school learners and members of the public to various aspects of science and technology" (2016: 6). They do so through their science and technology exhibits and programmes. In addition, they have outreach programmes focused on

creating awareness and teaching about science and technology in disadvantaged areas. As such, these centres are dominant spaces for promoting science in the country. Moreover, the Decadal Plan (2022-2032), which is tasked with implementing the White Paper (2019), in one of its policy intents of creating a science literate and science aware society, aims to "establish more science centres in collaboration with provincial education departments to spatially match science centres to districts in line with the District Development Mode" (DSI, 2023: 68).

### *Science Communication*

Pertaining to science communication, Gavhi-Molefe and Nemutudi, co-authored the book chapter titled "Building Capacity for Science Communication in South Africa: Afrocentric Perspectives from Mathematical Scientists" (2023). They argue that South Africa may have well-developed policies on STI, however, there are implementation gaps in terms of the imperative for scientists to deliver a viable, meaningful, sustainable and impactful science communication agenda. This is due in large part to inadequate resources. Their recommendation is to equip and grow the critical mass of science communicators in the country through a holistic, socio-cultural and ethical framework that will foster capacity-building towards an Afrocentric programme.

The book *Science Communication in South Africa: Reflections on Current Issues* (2019), edited by Weingart, Joubert and Falade, also addresses science communication. The editors identify three specific challenges to science communication. Firstly, they note that despite South Africa incurring considerable cost over the past three decades of implementing science policies, there is still no serious evaluation of the effectiveness of science communication due to methodological weakness and lack of clear linkages to particular communication programmes (2019: 4). Secondly, social media and the internet, despite the initial excitement of it being able to bypass traditional journalistic intermediaries, has also proven to be a vehicle for spreading false information (2019: 5). The third challenge that they identify is a structural problem where there are no clear-cut criteria for the selection of science content that should be communicated to the public, given the vast accumulated scientific knowledge (2019: 6). In this respect, Guenther et al. (2018) argue that what is communicated should be based on everyday life, socio-economic contexts, and immediate interests and needs, and there should be a pragmatic focus to science communication.

### *Science Engagement*

With respect to public engagement, the Science Engagement Strategy (2015), includes all knowledge fields and it integrates the natural sciences, engineering, social sciences and humanities, to instil the value of public engagement that fosters a broad and progressive understanding of science. The strategy has four main strategic aims. Strategic Aim 1: To popularise science, engineering, technology and innovation as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers; Strategic Aim 2: To develop a critical public that actively engages and participates in the national discourse of science and technology to the benefit of society; Strategic Aim 3: To promote science communication that will enhance science engagement in South Africa; and Strategic Aim 4: To profile South African science and science achievements domestically and internationally, demonstrating their contribution to national development and global science, thereby enhancing their public standing (DST 2015: 3).

Joubert (2019) comments on the science awareness, communication and engagement mandates and directives specified in the White Paper (2019), in terms of what is expected of scientists and research organisations. These directives include a fixed percentage of public science funding allocated to raising science awareness; new legislation to coordinate science engagement activities across the South African science system; research training and development grants to science councils and public universities with the condition to communicate their research to the public. Furthermore, the White Paper advocates specialised training to develop the engagement and communication skills of journalists, scientists, students, learners, educators and science interpreters (Joubert, 2019). However, Joubert finds that the willingness of scientists to facilitate scientific communication will usually depend on age, gender, research field and a sense of moral obligation.

### *Science Education*

Finally, in terms of the science education imperatives to society; science centres are positioned as informal education environments that are learner, teacher and public facing. According to Uzun and Besir (2022), the exhibition areas of science centres should be the focal point as educational areas. They should be interactive and allow for exhibitions to be touched and played with. In this way, technology themed exhibition areas in science centres make the greatest contribution in terms of informal education.

### *Science Centres and STI*

This paper draws on one case study to demonstrate the kind of technological change that is already taking place at an exponential rate, which is the ICT and Youth Development programme at the Sci-Bono Discovery. Sci-Bono is the largest science centre in the Southern Hemisphere in terms of size, number of exhibitions and the scale of projects. The Sci-Bono Discovery Centre was established in 2004, and was created to provide hands-on, interactive experiences for visitors of all ages. The Centre has a range of exhibits and activities, including a science theatre, a robotics lab, and a range of interactive displays and activities that focus on different scientific concepts. It also has a range of educational programmes and workshops for learners of all ages, including primary and secondary school learners. A pivotal role it plays is as a hub for STEM-related activities in the region, and hosts a range of events such as the annual Science Fair and the National Science Olympiad.

The Centre has played an important role in promoting STEM education in South Africa. It provides a unique opportunity for learners, particularly those from disadvantaged backgrounds, to engage in hands-on, interactive experiences that are not normally available in their schools. It has provided a platform for learners to explore different scientific concepts, and to develop their skills in science, technology, engineering, and mathematics. Activities at the Centre include a range of educational programmes and workshops for learners of all ages, which helps to bridge the gap between school and the real world.

The Centre has also been successful in engaging with the wider community, and has become a hub for STEM-related activities. It hosts a range of events, including the annual Science Fair and the National Science Olympiad, which provide an opportunity for learners to showcase their scientific knowledge. Some of its successes include engaging with local businesses and industry, and has been able to develop partnerships that have helped to promote STEM education in South Africa as well as in the region.

The Sci-Bono Discovery Centre has been successful in promoting STEM education in South Africa. It provides a unique opportunity for learners, particularly those from disadvantaged backgrounds, to engage in interactive experiences, and to explore different scientific concepts. The Centre has also been successful in engaging with the wider community, and has become a hub for STEM-related activities. Furthermore, it engages with local businesses and industry, and has been able to develop partnerships that have helped to promote STEM education in the region. Its promotion of STEM education has provided valuable lessons for other science centres around the world.

### *Sci-Bono and the Fourth Industrial Revolution (4IR)*

The Sci-Bono Discovery Centre in South Africa has made inroads into the Fourth Industrial Revolution through the use humanoids in a variety of ways as educational tools. Humanoid robots are robots that resemble humans in some form and are capable of performing certain tasks. The centre uses humanoid robots to teach various topics such as science, technology, engineering, and mathematics (STEAM) to school-age children. The robots serve as a hands-on way of teaching complex concepts, allowing children to engage and interact and learn from robots in a tangible and practical way, in real time.

The Centre has four main humanoid robots, each of which is programmed to perform a different task. The robots are programmed to interact with children and answer questions they may have. They are also programmed to help children learn basic math and science concepts, such as addition, subtraction, and the scientific process. The robots can be programmed to demonstrate experiments to the children, allowing them to interact with the robots and learn the concepts in a more engaging way.

The Centre also uses humanoid robots to teach coding and programming. The robots can be programmed to move in certain ways and follow specific instructions. This allows children to learn the basics of programming by controlling the robot and seeing the results of their programming in real time. The robots can be programmed to play games with the children, such as Tic-Tac-Toe, allowing them to learn programming concepts and problem-solving strategies. The Centre's use of humanoid robots as educational tools is an innovative way to engage children and teach them STEM concepts. The robots allow children to interact with the robots in a tangible way, and the robots are programmed to teach complex concepts in an engaging way. The use of humanoid robots as educational tools has proven to be an effective way to engage children in STEAM topics.

An overview of its 2022-2023 annual report period of Sci-Bono demonstrates the STI and ICT interventions pertaining to the 4IR targeted predominantly at the youth in partnership with the public and private sectors. The Sci-Bono ICT and Youth Department is dedicated to empowering individuals and communities through digital literacy, innovation, and technology-enabled learning experiences. It houses the ICT Academy, accredited by the MICT SETA, Cisco Network Academy, Cisco Academy Support Centre, Cisco Instructor Training Centre and Microsoft Certiport Centre. Over the past year, the department achieved several exciting milestones. One highlight was Sci-Bono being selected to implement the South African pilot of the Intel AI for Youth programme, a global initiative in 11 countries to facilitate entry and excellence in the technological sector, with a special focus on artificial intelligence (AI). Another was the ICT Academy achieving premier status as a leading Instructor Training Centre (ITC) through the Cisco Network Academy, ranked among the top 15% of the Netacad Partners.

Ongoing projects for the department are the Sci-Bono Clubhouse, a collaborative space for youth aged 8-18 to explore cutting-edge technologies like 3D printing, coding and robotics, virtual reality, artificial intelligence, music and video production, and programming. Off-site, the department is engaged with local communities by way of the Dell Solar Mobile Classrooms situated at 4 schools in underserved areas to provide access to technology and digital education where it is most needed. Additionally, the centre supports the GDE Multi Certification Skills Program focused on the GDE priorities for Multi-certification under the Reorganisation of Schools, which is driven mainly through the Section 17 Governing Body (GB)-Twinning programme and the Schools for Specialisation (SOS). The programme provided skills and training leading towards certification in coding and robotics, drone technology, digital literacy, Microsoft Office Specialist, Cisco Introductory Courses, and Artificial Intelligence (AI) for Youth.

Key strategic partners collaborate with Sci-Bono to enhance education through technological integration by providing financial support, mentorship opportunities, and access to advanced technologies for the benefit of the ICT Centre's programmes. Long-term partners include Dell Technologies, SAP, Cisco Network Academy, Air Liquide and Simplon.co. The ETDP SETA and the Gauteng Department of Education partnerships facilitated the delivery of End User Computing Learnership to 400 teachers in all 15 districts across Gauteng. Partnership with the German Development Corporation (GIZ) and the Department of Higher Education and Training enabled the training of 1500 TVET Instructors to help improve the quality of vocational training in South Africa. The centre continues strengthening strategic partnerships with corporate entities in the technology sector. The partners provide financial support, mentorship opportunities, and access to advanced technologies for the benefit of the ICT Centre's programs. Effectively, the corporate partners enable underprivileged individuals to access digital education opportunities, thus ensuring participation in the digital economy.

Through its ICT projects and programmes, the Sci-Bono ICT Centre has made significant strides in promoting digital competencies, innovation, and technological skills among unemployed youth, learners, TVET Lecturers, teachers, staff of the national libraries and communities during the reporting period. The Centre's commitment to providing access to ICT resources, delivering high-quality training, and fostering partnerships has positively impacted thousands of individuals, not only over the past year but for more than a decade. These efforts certainly contribute to the overall network of science centres nationwide. However, it should be borne in mind that all these initiatives and activities occur within the larger context of South Africa's NSI, STI, 4IR, political, social and economic imperatives. With specific relevance to the discussion in this section, the ethical imperatives undergird this multidimensional and multifaceted evolution of society.

## Conclusion

The discussion of the Framework for the Promotion of Excellence in a National Network of Science Centres (2005) at the micro level of science centres demonstrated the role that SAASTEC member organisations play in the broader STI and NSI landscapes. The role of science centres in the South African NSI and STI landscape is primarily science awareness, communication, engagement and education. In addition, science centres are actors in STI in term of informal education provided to both the youth and the general public. Furthermore, science centres play a key role in the 4IR and have a shown a demonstrated history of uptake of new technologies and innovations that have implications for futuristic science.

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