NATIONAL SCIENCE AND TECHNOLOGY FORUM

ON

BASIC SCIENCES FOR SUSTAINABLE DEVELOPMENT

26 AND 27 OCTOBER 2022
Virtual Online Meeting

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DAY 1

WELCOME TO PARTICIPANTS AND INTRODUCTIONS; PROGRAMME, OUTPUTS, AND INTENDED OUTCOMES (MS JANSIE NIEHAUS, EXECUTIVE DIRECTOR, NSTF)

Ms Niehaus welcomed everyone to the NSTF Discussion Forum on basic sciences for sustainable development.

The basic sciences were often neglected when talking about top researchers and science achievements in South Africa yet they formed the foundation for any specialised direction in science and research that might flow from that.

The speakers were experts in their fields and their work related to sustainable development as expressed by the United Nations (UN) in its all-encompassing Sustainable Development Goals (SDGs).

THE IMPORTANCE OF PARTICLE PHYSICS AS THE FOUNDATION OF CUTTING-EDGE RESEARCH AND ITS IMPLICATIONS (PROF. BRUCE MELLADO, DIRECTOR: INSTITUTE FOR COLLIDER PARTICLE PHYSICS, UNIVERSITY OF THE WITWATERSRAND (WITS), ITEMBA LABORATORIES, NATIONAL RESEARCH FOUNDATION (NRF); AND WINNER: TW KAMBULE-NSTF RESEARCHER AWARD 2021)

Prof. Mellado introduced the physics case, what kind of science drove the research that he was involved in and the work he has done with regard to the Higgs boson. In trying to attain the goals, it was necessary to deal with a tremendous amount of technological challenges that once solved, created solutions to problems beyond practical physics, such as the Big Data problem and the implementation of artificial intelligence (AI) in modelling. In 2020, Prof. Mellado and his team started contributing to the modelling of the coronavirus disease of 2019 (COVID-19) pandemic using techniques developed at the Large Hadron Collider (LHC)at the European Laboratory in the European Organisation for Nuclear Research, known as CERN.

A particular size or distance was assigned to a particular field of physics. The notion of distance was extremely important to classify what each filed in physics did. The LHC and the Square Kilometre Array (SKA) were at different extremes yet had similar goals. One of the key ingredients of the synergy of small distance exploration versus large distance exploration was the origin of mass in the universe. It was important to ensure a strong synergistic connection between particle physics and cosmology, which revolved around the origin of mass in the universe.

In the small frontier the known matter was composed of atoms of a particular size (minus 10 meters) and as the energy of collisions and the energy of the exploration increases, it became easier to resolve what was inside the atom. For over 100 years it has been known that the atom is composed of a very heavy and compact nucleus with electrons orbiting around it in a particular set of trajectories. As the energy of collisions was enhanced, particle physics emerged from nuclear physics and became a distinct field in physics that explored the sub-structure of the nucleus by looking at the sub-structure of its components (the proton and the neutron). Inside the proton and the neutron were constituents known as quarks that were even smaller and required more energy to explore. To date, the quarks have been thought of as elementary particles. The forces of nature also have to be taken into account. The elementary particles that matter was composed of interacted with each other. So far, four types of interactions have been identified: gravity, strong interaction (the force binding protons and neutrons together, typically referred to as a nuclear force), electromagnetism and the weak force (related to a particular type of nuclear reaction). In the context of the standard model of particle physics, electromagnetism and the weak force were united into the electroweak interaction. This led to the standard model of particle physics that explained what the known matter in the universe was composed of in terms of quarks and leptons, which were the building blocks of matter and organised in terms of three generations of matter. The particles interacted with each other through mediators that carried forces.

The Higgs boson played a very particular and well-defined role, distinct from any other particle in known matter in the universe. It was responsible to provide mass to quarks and leptons and also the W and the Z boson, and did this with a particular mechanism that was proposed in 1964 by a group of theorists who were awarded the Nobel Prize in 2013 after the discovery of the Higgs boson in 2012. The Higgs boson was very important not only because it revealed the mechanism through which known mass was acquired, but also because it opened the door to exploring and trying to understand what kind of matter existed in the universe and how that matter was generated.

An accelerator such as the LHC can be thought of as a very powerful microscope. The LHC has been the energy frontier since 2010 and will be taking data till the beginning of the 2040s. It was a system of magnets that kept protons in a circular trajectory and contained a number of experiments that recorded the collisions, presenting a Big Data and AI problem, and more recently connected with the problem of modelling the COVID-19 pandemic. Particle physicists were able to deal with complex problems of modelling because they were able to work with tremendous amounts of data produced by the LHC. The South Africa-CERN consortium was a fairly large community that contributed to A Large Ion Collider Experiment (ALICE), A Toroidal LHC Apparatus (ATLAS) and Isotope Separator On-Line Device, (ISOLDE) experiments and had theoretical and technology transfer components.

Essentially, particle physics used accelerators to bring particles to very high energies close to the speed of light and collide with each other head-on. Through the formula of special relativity ($E = mc^2$), energy was injected to create mass (heavy particles), which gave birth to the Higgs boson - a very short-lived particle that decayed almost instantaneously into something else. Sensors and instrumentation detected the products of the decayed boson. The ATLAS detector and other detectors were built primarily to capture the decay of the Higgs boson by ‘finding a needle in a haystack’ in large amounts of particles that were of no interest to particle physicists.

A lot of data that accumulated from 2011 and 2012 was used to establish whether there was evidence for a new particle and a new particle was modelled according to the standard model prediction. Another channel was used to collect data from a lot of two photon events and gradually an accumulation of events emerged in the same place. By combining the two channels around the first half of 2012, it was possible to establish unequivocal evidence that a new particle had been discovered. This discovery was the most important event in the lives of the researchers involved. Particle physicists created large amounts of data that needed to be disseminated, exchanged, analysed and communicated to scientists and others all over the world. It was due to this that the first protocols for communication through emails, the World Wide Web and the internet in general were created for the first time. This was one of the best known spin-offs that CERN has given to the world and one of its most famous contributions to technology transfer.

One of the most important aspects of particle physics, the LHC, presented a Big Data challenge that drove a lot of the technology transfer stemming from the LHC. The challenge of particle physics was that going to smaller and smaller distances and probing what was happening in the micro world of fundamental interactions, meant that particle collision needed to happen more often. To be able to discover the Higgs boson, the LHC had to reduce the time between collisions to 25 nanoseconds, which was an amazing technological advancement. Essentially, the LHC collided clouds of protons forty million times a second and provided data forty million times every second, and the detectors were required to record that data constantly. This tremendous challenge led to petabytes of data per second. The core of the Big Data problem was that the concept of the LHC was put forward in the 1980s and the main technological methodologies and methods were designed in the 1990s. The fact of the matter was that the Higgs boson was produced very rarely. Billions and billions of collisions had to be created to present one Higgs Boson candidate and many Higgs Boson candidates were necessary to establish evidence. This was resolved through a series of steps that composed the Big Data problem. The real time decisions typically took microseconds to seconds depending on the level of accuracy required. Computing technologies of today were able to handle hundreds of megabytes per second to create a computing model referred to as the Worldwide LHC Computing Grid (WLCG) that South Africa was a member of. In 2017, there were about 167 WLCG sites in 42 countries to address the Big Data challenge. A lot of tech transfer has taken place as a result of the fact that electronics were needed to process huge amounts of data. There were also examples of tech transfer activities in medical physics from techniques that were developed at CERN as well as those originating from nuclear and particle physics.

Science in general has been adopting machine learning in a more multi-dimensional way in the past five years or so. The scope and span of techniques and algorithms has become mind-boggling, and there has been an explosion in the integration of more sophisticated machine learning techniques into the data stream with a lot of spin-off into technology transfer through the activities at CERN.

The Institute for Collider Particle Physics has contributed to the management of the COVID-19 pandemic in South Africa as well as the post-COVID-19 world, and worked together with CERN to provide broad impact and further enhance technology transfer along the lines of the UN's SDG methodologies and the contribution to SDG#3.

When it became evident that South Africa was going to face a COVID-19 pandemic in early 2020, Prof. Mellado was called on to be part of a team of experts that led modelling for the Gauteng Province using classical modelling techniques in epidemiology in conjunction with AI. Machine learning learns and models from the data and the implementation of machine learning into classical modelling to enhance classical modelling and bring it to a whole new level of understanding. Through this work, a consortium was created that included international collaborators and was recently expanded to look at how AI would help in a post-COVID-19 world.

Some of the cases where AI was used to enhance classical modelling as a means to resolve burning questions were presented.

- During the early months of the pandemic, the modelling was mainly hotspot driven. The task of government policy-makers at all levels and on the ground was to identify where the pandemic was growing fastest and the hotspots, and enact interventions that would help suppress the growth of those hotspots. Information from communities that was necessary to predict how the hotspots would evolve was not available and this put the team under immense pressure. The circumstances demanded a particular brand of AI called unsupervised learning, which did not require large amounts of pre-existing knowledge and generated clusters. Classical techniques were embedded into the clusters to model how the clusters would emerge and evolve over time. AI was critical in defining the clusters of hotspots and in classifying them. A tool was created that allowed the population and policy-makers to understand the location of the hotspots, how fast they were growing and how dangerous they were. The team developed the AI and monitored social media to identify hotspots.
- In 2020, the South African National Defence Force (SANDF) needed information about when waves of the pandemic would take place. This was a difficult question for the team because classical models could not predict when a wave would occur. AI techniques were used to create and generate early detection algorithms. This was done by training a particular type of machine learning algorithms on historical data. These algorithms indicated red flags that alerted the authorities and public to a wave in the pandemic about two months before it occurred.
- During the first half of 2021 there was a scarcity of vaccines but by mid-2021 vaccination hesitancy became the bigger problem. AI was used in the planning and organisation of the phased rollout of the vaccine and was introduced in phase 2 to help provide answers about the most efficient way to administer the vaccine to have maximum impact. The team used data from the Department of Health, especially hospital and mortality data, and certain techniques to create classifications of patients, and was able to devise a smart algorithm to indicate the optimal path of delivery.
- From a modelling standpoint, vaccination hesitancy was a much more complex phenomenon than anti-vaxxers or people who chose not to get vaccinated. The government commissioned a survey that concluded that only 15% of the population was against taking the vaccine. Policy-makers were alerted to the fact that the pace at which the vaccines were being administered was inconsistent with the 15% vaccination hesitancy. In trying to understand the vaccination hesitancy, the use of natural language processing, a branch of AI that looked at the texts of Tweets and other social media, was considered. A sentiment analysis of Tweets was established to achieve the biggest possible efficiency of the understanding of the texts and a dashboard was created to plot the location of the negative and the positive sentiments in each province.

Post the COVID-19 pandemic, AI has begun to be used in a more sophisticated and multi-dimensional way. All possible sources of data were included in a more systematic way to develop early detection algorithms for new pandemics. Satellite data that covered the entire African continent provided a tremendous amount of information about pandemic outbreaks. AI was the future of pandemic detection. Large quantities of data (satellite, clinical, climate, epidemiological, World Health Organisation (WHO), Centres for Disease Control and Prevention (CDC), water, air, social media, citizen science) will be collected into a massive AI algorithm used to alert WHO governments about the emergence of new pandemics. The integration of these datasets and the modelling stemmed from AI. Particle physics was moving in the direction of enhancing dimensionality and complexity, and has entered an era of deep learning with a huge amount of variables and indexes.

Malaria was also being addressed through the implementation of AI using data from Ghana and Kenya. It was important to correlate the outbreak of malaria as a showcase of disease with factors on the ground that can be monitored with satellite data. There have already been several studies in the field of malaria but not on the use of AI. Combining all the information available brought a better understanding of how the pandemic would evolve and allow for outbreaks to be predicted. Machine learning was extremely helpful at combining very large amounts of high dimensional data to create models and scientists have learnt how to extract the required information from satellite data.

The Institute for Collider Particle Physics has launched a very large international project with CERN as a very important stakeholder to provide answers to public health concerns about air quality and its relation to a huge array of health conditions and many deaths, and its strong connected to vulnerability. A consortium on air quality monitoring was established comprising about 20 stakeholders globally including industries that provided in-kind contributions. One of the biggest stumbling blocks to air quality monitoring was the cost of sensors in the Global South and so one of the proof of concept projects was about developing open source low-cost sensors. The idea was to combine low-cost technologies into a low-cost device to enhance the ability of governments to roll-out sensors more widely. An air quality monitoring system was the flagship project of the CERN Green Village and an initiative of CERN to demonstrate that particle physics has a very broad impact and was also very green. A sufficiently accurate low-cost system will be deployed in order to establish the quality of air and detect poor quality air and highly polluted areas.

UNDERSTANDING ECOSYSTEM PROCESSES IN ORDER TO DEAL WITH CLIMATE CHANGE (MR MTHOKOZISI MOYO, PhD CANDIDATE: GLOBAL CHANGE INSTITUTE, SCHOOL OF ANIMALS, PLANTS AND ENVIRONMENTAL SCIENCES, WITS)

Mr Moyo gave a brief introduction to climate change and spoke about the work he had done for his Masters and the work he was currently busy with as part of his PhD studies. The first step in dealing with climate change was to understand the processes that drove climate change and what exactly was happening. Climate change was a very broad topic that covered many aspects. Climate change involved a lot more that dry and barren landscapes such as those found across Africa. The global climate was changing and it was necessary to study the things that influenced climate change to be able to detect it. Recent news headlines highlighted the kind of devastation that climate change can bring and the challenges Africa faced in this regard, as well as the importance of understanding climate change and its influence on our day-to-day lives. Climate change was not only about increasing temperatures, less rainfall and rising sea levels globally, but also about the destruction of infrastructure, famine, extinction and a migration crisis.

Mr Moyo’s Master’s work focused on the phenology of high altitude and low latitude grasslands. Phenology was the study of the timing of biological events in plants and animals. In this case, it referred to the growing season. Grasslands were very important in the global carbon cycle and did not have biomass but had soil carbon stores. Grasslands took up more carbon than trees as they stored all the carbon in the soil. Most of the work on the topic of high altitude and low latitude grasslands has been done in the northern hemisphere and was not necessarily applicable in the southern hemisphere. The only place where these kinds of grasslands were found was in the eastern part of South Africa. The vegetation in this particular area was mostly montane grasslands but over time much of the area has been transformed by agriculture, mining and human settlement.

The aim of the study was to develop a phenology model for the Afromontane grasslands and climate data was needed to do this. A dataset covering a 110-year period (1904 to 2017) was constructed. A weak trend of decreasing rainfall and an increase in temperature were found over that period. The study then looked at what these results meant for the growing season (the time of the year when conditions that are good for plants to grow) in particular, although the difference in temperature and rainfall also affected other factors. It was found that the length of the growing season has increased and this was consistent with other studies done around the world. This extension could be due to an increase in the amount of carbon dioxide emitted in the atmosphere but there was no single explanation for this result. It was necessary to look at each and every process related to climate change to be able to understand the factors that influenced the length of the growing season.

Another study that Mr Moyo was involved in looked at how drought affected shrub dieback in the Karoo, particularly the influence of the 2015 drought. The study tried to understand which factors affected the growth and survival of Karoo vegetation, and how this could change in future. The aim of the study was to conduct a climate analysis of the region and link it to understanding the effect of the 2015 drought on the vegetation in the area. The severity of the drought was compared to that of previous droughts. Hot indices (the number of hot days and warm nights) and cold indices (the number of cold days) followed the same trend and was consistent with the increase in temperature. A graph analysing the length of the drought showed the standardised precipitation evaporation index (SPEI) used to measure drought. The SPEI integrated the temperature and the rainfall and took into account the soil moisture. This was another confirmation that climate change was taking place and needed to be taken more seriously.

Mr Moyo's PhD focused mainly on seasonality, which was the predictable yearly cycle of an environmental variable and has an effect of on many variables such as ecosystem functions and community structure and composition. The main kinds of seasonality were temperature seasonality and wet dry seasonality, or rainfall seasonality. Temperature seasonality was controlled by temperature and was more important in the more temperate ecosystems where temperature controlled the biological processes. Rainfall seasonality drove seasonality in Africa as it synchronised growth and reproduction with the availability of water. The distribution of plants and animals was controlled by the lack of water during certain times of the year. Climate change has been happening for many centuries. Changes that occurred in the Earth 65 to 55 million years ago made it possible for wet-dry seasonality to be established. The Earth becoming drier and warmer was not something new but has been happening at an accelerated pace in recent years. Seasonality was also a driver of community change and was affected by climate change. A climate that gets warmer or drier becomes more seasonal and this has an impact on the distribution of plants and animals. The persistence and coexistence of many populations depends on seasonality.

The study tried to identify the traits that plants and animals had to deal with seasonality. The traits were grouped according to avoidance, flexibility and tolerance. Plants and animals that needed a lot of water to survive were most likely to have avoidance traits and those that needed less water to survive were most likely to tolerate seasonality and climate change. Rainfall seasonality represented how rainfall was distributed within the year in a particular area. This distribution has significant consequences on the magnitude, the intensity and the length and timing of the dry season, which were all important factors to consider in measuring wet-dry seasonality. Herbivores were classified according to their characteristics, which can be used to assess how they were affected by seasonality. Beta-diversity has to do with the extent of change in community composition in relation to the environment. Some species can survive in all kinds of conditions but only a certain group can survive in specific conditions. The study aimed to identify species that were characteristic of seasonal environments and the Socio-Ecological Observatory for Studying African Woodlands (SEOSAW) network was used to do this. It was found that areas with high biodiversity have low seasonality and areas with low biodiversity have high seasonality. Climate change meant that a lot of biodiversity would be lost because the climate will become more seasonal over time.

In summary:

- Seasonality was important in African ecosystems as it controlled the distribution and ecology of plant and animal species.
- Temperature has increased and rainfall has decreased during the past 100 years. There was an

increased likelihood of drought and droughts lasted much longer.
- The high beta-diversity across gradients of seasonality in South Africa, influenced by turnover, meant that some species were specifically adapted to this particular environment.
- Understanding ecosystem processes was the first step in being able to deal with climate change by adapting and taking steps to mitigate further climate change.

Q&A and Discussion

In response to a question of clarification about whether grasslands had biomass, Mr Moyo explained that most of the biomass from grasslands was below ground as carbon was stored in the roots, and that trees had more aboveground biomass than grasslands. Other plants in grasslands were also important for the carbon cycle but no studies had addressed this to date.

BASIC SCIENCE AND INNOVAITON TO PROVIDE CLEAN WATER/SANITATION - ADVANCEMENT IN WASTEWATER TREATMENT TECHNOLOGIES (DR FARAI DZIIKE, RESEARCHER: MATERIALS CHEMISTRY, DURBAN UNIVERSITY OF TECHNOLOGY (DUT))

Visitors to Durban were advised to bring their own water as the city's water supply and most of the beaches have been shut down because of extremely high levels of E.coli from raw sewage that was flowing directly into the ocean bringing the threats of a health risk to the community. In addition, there was a failure to implement wastewater treatment technologies to produce potable water and the area had experienced extremely high temperatures causing surrounding streams to dry up. Resolving this critical situation relied on input and assistance from basic science, research, innovation, technology development, including water treatment technologies. Different research focus areas were being used to try and come up with innovative technologies for advancing the current technologies towards improving water quality.

Around 90% of patients in South African hospitals suffered from illnesses and diseases that can be traced to the quality of the water they used. One in every three people in Africa did not have access to clean and potable water and the continent continued to experience population growth, urbanisation and increased household and industrial water use. The situation had worsened over time and required a proactive response. The degree of contamination had far exceeded the capacity of the current conventional water treatment methods to produce water that was safe and potable for human consumption. Conventional water treatment and methods in South Africa were never designed to cater for the current high levels of contamination of water. The infrastructure was outdated and much of it has deteriorated and would cost too much to replace. Conventional water treatment methods were not capable of dealing with the wide range of chemical, pharmaceutical and cosmetic products being released into the water by industry and households. In 2021, explosions in petrochemical purification plants had led to the spilling of thousands of tons of crude oil into the rivers and the sea, causing widespread contamination of water sources and the collapse of the already ailing infrastructure. The situation called for alternative sources of water to be found and advanced technologies of wastewater treatment to be implemented.

Wastewater treatment plants used processes that tried to clean the raw sewage, the primary, secondary and tertiary effluent, and then tried and deal with the sludge to minimise the contaminants in the water that eventually ended up in the conventional water treatment plants. However, these processes had become inadequate and more effective and efficient technologies were needed.

A very efficient technology called electrodeionisation equipment (EDI) was not available in this country and used a lot of energy, which would not be helpful due to the ongoing energy crisis. EDI made use of activated sludge treatment using aerobic wastewater treatment processes and its aeration stage was particularly energy intensive. As a result, it became very expensive particularly for those municipalities where funds were not prioritised for service delivery and other essential applications. Another technology, the self-respiring membrane aerated biofilm reactor, was expensive in that the membranes had to be removed and replaced frequently resulting in downtime. There was also thermal wastewater treatment that used heated water that was evaporated and condensed so that multiple processes can be carried out in one stage. The evaporation removed most of the suspended solids and the dissolved material. The temperature at which water was evaporated was moderated so that only pure water evaporated and was collected in a distiller. This technology used excessive amounts of energy and its high carbon footprint made it undesirable. A technology that tried to minimise energy use was known as membrane bioreactor technology. It was specifically designed for liquid filtration and separation processes and used technical parameters such as microfiltration, ultrafiltration and nanofiltration in reverse osmosis. However, filtration across the membrane caused clogging of the membrane surface, which necessitated downtime to remove the membranes and clean or replace them.

Technology that used filtration processes and membranes as its major separation process, complicated the entire mechanical and engineering setup, which, compounded by high energy usage, became a very difficult process to implement. There were no examples of where this technology was used for large scale operations such as in communities, and using it in industrial processes where ultra-pure water was required would substantially increase the cost of manufacturing products. If the EDI technology was up-scaled for municipal wastewater treatment, the water produced would become inaccessible because of the cost of producing clean water.

The continued use of conventional wastewater treatment methods will leave a very large carbon footprint and only remove simple organic contaminants in secondary biological treatment. The operations and design of the current plants cannot deal with complex organics, especially those from pharmaceuticals and personal care products. During the COVID-19 pandemic, the importance of advancing technology to deal with the virus was highlighted. DUT’s Institute for Wastewater Treatment advised the National Coronavirus Response Board on the prevalence of the virus in wastewater.

The intended purpose of purifying water can be negated by one stubborn contaminant that persisted throughout the whole process of conventional water treatment. This highlighted the need for tertiary methods even if they were expensive. Technologies such as advanced oxidation were being studied by numerous research groups to look at the use photocatalytic methods to reduce the amount of energy used by accessing energy directly from the sun and avoiding the use of chemicals to ensure a cost effective and sustainable process with a very positive environmental impact. The technology that was developed was an add-on to conventional water treatment. This means that water has to go through an additional unit of purification called the photocatalytic reactor unit to deals with stubborn dissolved organic contaminants at all levels of molecular existence. Titanium tetrachloride was converted into titanium dioxide. The materials were fabricated into nanorods and nucleated in a hydrothermal process to produce radially aligned nano-rutiles (RANR). The purpose of doing this was to increase the surface area over which the organic contaminants can be trapped and broken down through a photocatalytic process. The catalyst was simply activated by sunlight and the electro-chemical shift facilitated the photodegradation of the organic molecules such that the compounds were broken down into CO_2 and H_2O. There was no need for further treatment after this process. The bad smell, taste and colour of water was dealt with in one step through the photocatalytic process.

Detailed studies of the nature of the catalytic material showed that it was stable both chemically and thermally. Because of its stability and electrochemical nature, it was very easy to manipulate the titanium dioxide and fix it in a fixed bed reactor where it can be used as a catalyst in a process unit that targeted dissolved organics and purified them through a simple process. In addition to its photocatalytic activity, active catalysts can be loaded on the material and carbon fibres can be grown to produce a double effect during the purification process where photocatalytic degradation was performed on the surface of the titanium dioxide itself. The carbon nanofibers, which were attached on the tips of the catalyst, absorbed materials and enhanced the levels of purification. Where the titanium dioxide has failed to break down contaminants, they were dissolved by the carbon nanofibers and removed from the water system.

Studies that have been done at PhD level showed that different active catalyst materials can be loaded at selected sites along the radial length of the titanium dioxide that was being shaped into a RANR. This technology has been developed into innovation technology that was being commercialised. A prototype has been developed using a fixed bed mounted into a laminar flow reactor. As the water ran through the laminar flow reactor (using a solar powered water pump) and was pushed through this laminar flow reactor with a fixed photocatalytic material, clean water was produced without any need for additional chemical treatment. This technology was at technology readiness level 5 and funding was being sought to upscale it for use at industrial level at one of the municipalities where it could be tested for large-scale application.

Q&A and Discussion

In response to a question about the availability of titanium in South Africa, Dr Dziike indicated that the KwaZulu-Natal (KZN) Provincial authorities had recently commissioned a USD 250 million titanium plant in Richards Bay. Titanium was reasonably cost effective and easily accessible.

In terms of the E. coli contamination of irrigation water in KZN, Dr Dziike explained that E.coli was a microbial material that can effect plants and animals and cause a variety of diseases. E. coli has had a bad effect on the quality of sugarcane grown in KZN. In one area of the province, an entire harvest had to be discarded as a result of the high level of E. coli in the irrigation water.

HOW DO BASIC SCIENCES LIKE BOTANY CONTRIBUTE TO HUMAN HEALTH? (PROF SAM MASHELE, DEAN: FACULTY OF HEALTH & ENVIRONMENTAL SCIENCES, CENTRAL UNIVERSITY OF TECHNOLOGY (CUT))

Botany is the study of plants. Most people were not familiar with the role that plants played in health and even though plants made up about 80% of all biomass, populations around the world knew very little about them. Talent in the field was being lost as many of the experts were getting older and very few young researchers were choosing botany, particularly the area relating to plants for human health.

Plants produced oxygen, maintained soil quality and provided food and habitats to other organisms. They reduced air pollution, captured CO_2 from the atmosphere and many had medicinal properties. Plants were deeply embedded in cultures worldwide and much was being said about the importance of ‘parenting plants’ for the health and wellbeing of humans. Plants were also being used as a substitute for meat and dairy in the diet and a plant-based was known to alleviate or lessen symptoms of diseases such as hypertension and diabetes, and prevent obesity and the contraction of certain ailments. The potential benefits of the derivatives of plants for human use, particularly as novel compounds in drugs used to fight cancer and other diseases, were being studied in the CUT laboratories.

Plants were programmed as molecular factories that were used in the development of prospective vaccines, for example. During the COVID-19 pandemic, a group of researchers worked on developing a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccine using plants. The beneficial uses of plants were only limited by the available knowledge and scientific resources, and imagination. Much was being done to stimulate interest in and disseminate information about the importance and value of plants. A better understanding of plants will contribute to sustainable development through the use of plants to the benefit of all people.

Exploring the use of particular plants as agents for novel compounds to treat a variety of ailments was not only about new drug development but also about ensuring the application of plants to improve the health of the population and protect people from contracting chronic conditions that wreaked havoc in society.
Pharmaceutical companies were interested primarily in plant-based single ingredient drugs. The CUT laboratories were collecting crude extracts from plants and testing them for pharmaceutical application. The concentration of the crude extract differed between plants according to region, and a number of factors influenced the concentration and the efficiency of each extract, highlighting the need for standardisation.

Over time, the emphasis has shifted from extracting medicinal compounds from plants to manufacturing synthetic compounds. Chemistry plays a role in the use of natural products as templates for structure optimisation programmes designed to make perfect new drugs. Pharmaceutical companies worldwide were moving in this direction and testing the new drugs to ensure their effectiveness and safety. Some of the botanical drugs, such as those used to treat cancer, had side effects but were usually less toxic or less cytotoxic than other drugs.

It has become evident over the years that complex diseases cannot be treated using a single ingredient drug. Botanical drugs were derived from plants using a crude extract rather than a single ingredient and were tested for efficacy and side effects, sometimes using *in vitro* techniques. The CUT laboratory has identified a number of compounds and was working with pharmaceutical companies to look at using novel chemical entities to treat complex diseases with a 'single silver molecular bullet' and to get the products into the mainstream medicinal market. The mutually potentiating effect of different components of different complex medicinal mixtures was very important because in most cases plants derivatives were not necessarily a particular active ingredient but a combination of ingredients that improved effectiveness.

Other research the laboratories were involved in looked at botanical drugs that were effective against the coronavirus and found that some of the drugs supressed the virus by 97% and were safe in that they had no negative effects. This research extended beyond the COVID-19 vaccine to possible alternative medication to deal with symptoms of the virus. The CUT laboratories were also involved in the commercialisation of botanical drugs that have shown to be effective. Most botanical drugs were not required to undergo clinical trials because their efficacy and safety has been proven over many years of use, and therefore they were able to be marketed as alternative medicine.

Society needed to be educated about the value of plants into the future. Plants were by far the most cost-effective and abundant renewable resource and were uniquely adapted to complex biochemical synthesis. The increasing cost of energy and chemical raw materials combined with environmental concerns associated with conventional pharmaceutical manufacturing, were reason enough for plants to become more compatible in the future. Farmers who adapted crop-growing to focus on health outcomes would benefit from the higher values and greater profit margins enjoyed by the health industry and as a result, the planet would become greener and the population healthier.

Q&A AND DISCUSSION

Patience Mphumbude asked whether ethnobotany still had a place in human health in the future without it necessarily being associated with or stigmatised by African traditional healing. Prof. Mashele was of the view that ethnobotany still had a future but people needed to be educated about it. Medical students were not taught about traditional medicines and medical practices even though they play an important role in health. These medicines needed to be tested and validated so that they can be part of the mainstream treatment for some of the most common conditions found in communities.

Ms Niehaus asked the speakers how their research could enrich the teaching of basic sciences at school and whether basic sciences should be integrated into the school curriculum.

- Prof. Mellado indicated that the Institute, in collaboration with the European Laboratory at CERN, had participated in master class activities over the years that included high school learners and university students who were taught how to extract information from data.
- Mr Moyo had taught learners from various schools about the biomes of Africa and the importance of environmental science during the time he worked in science engagement. The online manual could be accessed at: https://rise.articulate.com/share/RMQ63mci12bqHK5YFxb6dvm8AlTOcLst#/
- Prof. Mashele mentioned that CUT had started the process of decolonising the curriculum and incorporating traditional knowledge in the curriculum. South Africa was not only a consumer of knowledge from the West but also a provider of knowledge originating from Africa. Scientists from overseas came to this country to do their research on its indigenous plants and created their own knowledge from this country's indigenous knowledge. Mechanisms such as Intellectual Property (IP) were in place to ensure that indigenous knowledge was not exploited.

Prof. Mellado explained that physics and chemistry were basic sciences that have evolved over many years to develop fundamental science and research. There were many synergies between the Wits School of Physics and its School of Chemistry through material sciences, and this collaboration had continued for many years. A Centre of Excellence was put together on the basis of that collaboration.

Ms Niehaus inquired about the extent to which Einstein's predictions had been confirmed, particularly through the research at CERN. Prof. Mellado responded that Einstein's contribution to physics revolved around spatial relativity and general relativity. Spatial relativity (the fact that the speed of light was finite and nothing travelled faster than the speed of light) was known to be correct and formed the basis of the theory of physics today. One of the most important predictions of general relativity was gravitational waves and these were discovered recently confirming the predictions after about 100 years. The Nobel Prize was recently awarded to three physicists for the discovery of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO) experiment.

Prof. Mellado asked Mr Moyo whether machine learning had been considered to create predictive systems from the large amount of climate change data that was available. Open source software was readily available and incorporated many different algorithms that could be used for processing and developing data-driven models that can be combined with existing ones. Mr Moyo responded that although machine learning would help process data much faster, baseline studies were still needed to understand the system and the kinds of inputs that would go into models. Many models had been done using machine learning but they tended to not represent the real world and had a northern hemisphere bias. Local data was needed to generate models that were of value to the specific ecosystem being modelled. Prof. Mellado explained that the great advantage provided by machine learning was that it is able to create models that could be incorporated on classical models based on the local data. Plenty of local satellite and other climate data was available and needed to be analysed and incorporated into modelling to make it applicable to the specifics of an area or country. This was what AI offered. In the early stages of the COVID-19 pandemic there was a lot of debate about the applicability of the experiences of European countries in other parts of the world. It became evident that local models based on local data were essential to be able to make appropriate predictions.

Ms Niehaus asked about the possible implications of climate change on nutrition and diets. Mr Moyo's research did not address the effects of climate change on farm crops and animals, and the possible implications of climate change on people's diets. He did mention the relevance of the link between climate change and increased levels of disease faced by plants and animals. Prof. Mashele remarked that scientists were working to make plants more resilient to climate change through molecular engineering. With regard to diet, he suggested that people should eat less meat and dairy, and follow a balanced diet that included plants.

In response to a question about whether the basic sciences should be broken down into its various components at a specific point in the education system, Prof. Mellado explained that the connection between basic education and higher education had to be consistent. Basic education should pay attention to the connection between fundamental sciences, how they were taught and how mathematics played a role in bringing them together. This was the responsibility of the Department of Basic Education. Prof. Mashele pointed out that the move towards multi-disciplinarity allowed scientists from a variety of basic science disciplines to work together to ultimately bring greater impact and solve complex problems.

Gordon Branston (Zoom Chat) commented that wastewater treatment was a very important research topic in the context of high impact opportunities to address basic sanitation needs of communities. A research paper that provided a synergy nexus link on the role of wastewater treatment in achieving of the SDGs, showing that wastewater treatment contributed effectively in achieving 11 out 17 SDGs could be accessed at: https://www.sciencedirect.com/science/article/pii/S2772427122000729?via%3Dihub

Following the above comment, Mr Branston mentioned that he was interested to hear more about the nexus connections with the basic sciences, wastewater and the SDGs, more specifically using them as a strategic lever for transformational change in both education and policy, which is a critical issue. He suggested that ways to use the SDGs as strategic levers to highlight the nexus approach should be discussed. Researchers were in a prime position to take this forward.

Ms Niehaus suggested that the Department of Planning, Monitoring and Evaluation (DPME) was responsible for the measurement of the SDGs and reporting back to the UN, and could be invited by the NSTF to give feedback on the current situation with regard to South Africa's position on the SDGs.

Eleanor Richardson (Zoom Chat) agreed that there was massive scope for using AI to answer some big questions in South African ecosystems and biodiversity but much of the basic data was in private hands (researcher and/or industry). She asked how the private owners of data could be persuaded to give the data for use. Mr Moyo mentioned that he had encountered the problem relating to accessing data. From the perspective of ecology, most of the data was owned by people in Europe and the process to access the data was very long and complicated. It was also very difficult to access data held by South African government institutions and entities (such as the South African Weather Service). In some cases, the data existed but was not digitised. Data was expensive to collect and put together, although it had become cheaper to do this in recent years. Models required long-term data as well but this was a challenge.

Prof. Mellado added that the point raised by Ms Richardson was complex and needed to be addressed on a case by case basis. During the COVID-19 pandemic, a lot of important and relevant data was in the hands of private stakeholders. Numerous interactions between government workstreams and the public and the private sectors took place before those who needed the data were given access to it. Existing relationships with stakeholders such as the telecommunication companies facilitated access to data that helped with understanding mobility, which was very important in the context of the pandemic. Some of the attempts to access important data were unsuccessful. Private owners of data had a well-defined view of what it meant to share data and a strong sense of the value of data. Accessing data was a very complex process that needed to be carefully negotiated and had to be addressed case by case. Scientists together with government stakeholders and universities needed to engage actively in this process.

In terms of health and nutrition data, Prof. Mashele mentioned that sometimes data was not collected or was not collected in the right way. It was important to collect all the details and to store the data digitally. Unavailability of the correct data had a serious impact decision-making and policy-making at government level.

In response to a question about whether African or traditional plant-based medicine or food could be used as alternative treatment for animals, Prof. Mashele indicated that the norm was to vaccinate animals and give them antibiotics and hormones, which were absorbed into the tissue of the animals. By eating the meat, humans ingested these chemicals, which found expression in their health. He encouraged people to move away from eating a lot of meat, eggs and dairy products, and to voice their opinions about practices that impacted human health negatively.

Gordon Branston (Zoom Chat) asked whether access to remote sensing and earth observation data was an important constraint and if so why and how these tools could be used to link the research to relevant SDGs. Mr Moyo indicated that some of the remote sensing data was readily available, cost effective and downloadable for use by anyone. The biggest problem with collecting data was that there was no way of standardising different datasets.

Ms Niehaus asked the speakers whether they had worked with the South African National Space Agency (SANSA) in collecting data, particularly remote sensing data. Mr Moyo indicated that he had not worked with SANSA because his work required data for the entire African continent and not only South Africa. Prof. Mellado indicated that the Institute had interacted with SANSA over the years and has been working with satellite data for a number of years in different contexts and applications, which were moving towards public and global health problems. Most of the work done in this space came from the European Space Agency and the National Aeronautics and Space Administration (NASA) in terms of data collection as these agencies' satellites scanned Africa on a regular basis and provided their data for free and in formats that could be used and processed with AI.

Gordon Branston (Zoom Chat) commented that Earth Blox offered a code-free interface to Google Earth Engine, a multi-petabyte catalogue of satellite imagery and geospatial datasets with planetary-scale analysis capabilities to detect changes and map trends (https://youtu.be/uBa-fOD5Frs).

Ms Niehaus asked whether SANSA should be better supported to allow it to do more work of particular relevance to South Africa. Prof. Mellado mentioned that satellite data presented a goldmine of information and that this tremendous resource was not being sufficiently utilised globally and in South Africa, especially given that the data covered a wide range of applications related to the SDGs. Enhanced resolution was always good and therefore, a specific effort that looked into some of the scanning with high resolution would be beneficial to a variety of studies in South Africa. The idea of enhancing resolution in certain applications would receive support.

WRAP-UP AND CLOSURE

In conclusion, the speakers thanked the NSTF for the opportunity to share their work and remarked on the importance of the basic sciences for all learners because they were crucial for the future of science in the country. Forums such as this provided opportunities for interaction between researchers from different disciplines and stakeholders to enhance their ability to model and predict problems and issues of global importance beyond their own research.

Ms Niehaus thanked the speakers for giving their time and sharing their expertise and their insightful work, as well as the participants for their valuable contributions to the discussions.

DAY 2

WELCOME TO PARTICIPANTS AND INTRODUCTIONS; PROGRAMME, OUTPUTS, AND INTENDED OUTCOMES (MS JANSIE NIEHAUS, EXECUTIVE DIRECTOR: NSTF)

Ms Niehaus welcomed everyone to the second day of the discussion forum. The first day's discussions were interesting and covered a lot of ground in terms of basic sciences and sustainable development. The connection between cutting edge and important technology and issues was clarified, making the link between those and the basic sciences. The presentations dealt with climate change, ecosystems, Big Data, cutting edge technology with AI, the CERN LHC, issues around wastewater treatment technologies and botany's contribution to human health.

HOW THE BASIC SCIENCES SHOULD BE TAUGHT FOR ENVIRONMENTAL SUSTAINABILITY (PROF. MIKE BRUTON, MIKE BRUTON IMAGINEERING; AND WINNER: 2002 NSTF LIFETIME AWARD)

Teaching children in their home language through the formal education sector presented a challenge in Africa mainly because between 2000 and 3000 languages were spoken and the majority of the continent's 1.4 billion people lived in rural areas. Discussions on education have to deal with how the partnership between formal and informal education can be achieved especially in Africa given that its museums, science centres and outreach programmes made it possible to reach children in remote areas. The continent as a whole has poorly developed formal educational infrastructure. In 2012 only 20% of eligible children were enrolled in primary school and to date no African country has achieved universal primary education.

The original goal of science as defined by the Royal Society of London included the statement to simply do nature for the benefit of humankind. At that stage, people regarded themselves as superior to all other living things not necessarily dependent on them and people had the right to subdue nature for their own benefit. The modern goal of science was more informed and more nuanced. From the environmental perspective, science could be defined as 'to understand natural phenomena and processes, and learn to live within their limits'. This included allowing natural processes to continue at their normal rates. Learning to live within the limits of natural processes was one of humankind's biggest priorities.

A question posed by the International Science Programme (IPS) at Uppsala University about the justification for supporting basic sciences in low- and lower-middle-income countries was absurd as there was no reason why basic sciences should not be taught in these countries. In classifying countries, perhaps the 'developed world' and the 'developing world' should be referred to as the 'overdeveloped world' and the 'appropriately developed world' respectively. Almost all the causes of climate change arose in the northern hemisphere and although Africa contributed least to the causes of climate change, it stood to be impacted the most. Many African countries were fortunate in that they escaped the worst impacts of the first three industrial revolutions and were benefiting from the ‘Fourth Industrial Revolution (4IR)’. The sustainable ways of life that have been developed in many African countries were an example that should be followed by the so-called developed countries in the northern hemisphere. The second question posed by the IPS about whether support to the basic sciences would contribute to poverty reduction implied that poverty was the only problem in Africa and other parts of the so-called developing world, whereas there were many other problems that needed to be addressed.

The circumstances in Africa, including the educational challenges, emphasised the importance of teaching the basic sciences in Africa. Prof. Bruton gave some examples from his various books to substantiate this, including numerous South African and African inventions some of which were based on traditional knowledge. Africa was not only the cradle of civilisation but also the crucible of innovation. Major contributions by earlier cultures in Africa had laid the foundations for developments that subsequently occurred elsewhere in the world. There were many examples of how indigenous knowledge acted as a stepping stone into low, medium and high technology solutions to the problems that people faced. African people were problem-solvers and there were many examples of the beneficiation and commercialisation of indigenous knowledge and of how the basic sciences have been applied in African countries to make useful products. Africa’s contribution to science and technology in the world included several world renowned inventions and ought to be regarded on an equal basis with those of the northern hemisphere. Africa was particularly rich in social entrepreneurs who worked in adverse environments and developed products for the public good.

Teaching the basic sciences not only helped people to gain knowledge but also to understand natural phenomena. Learning about the basic sciences and the scientific method also helped people to learn about rational objective thinking (cause an effect). Many captains of industry have a scientific background and succeeded because they understood the scientific method and knew how to make evidence-based decisions. The basic sciences also taught people to be sceptical and acknowledge that a full understanding of everything would never be achieved. As part of the scientific method, the status quo and the knowledge of past generations needed to be challenged constantly to advance science. Knowledge of the basic sciences helped young people develop a skill set that made it easier for them to succeed in the modern world, and to climb the innovation ladder from low- to medium- to high-tech, which was a characteristic of innovation in Africa. Knowledge of the basic sciences also helped develop wisdom (knowledge applied to make good decisions) as well as a positive mindset and appropriate behaviour and lifestyle, influencing other to follow suit. This was particularly important in contemplating the impact of humans on the natural environment and rationalising lifestyles within the limits imposed by nature.

The concept of the education value chain focused on the need for formal and informal education to go beyond conveying information to communicating knowledge (information contextualised within the life circumstances of individual people) and using the knowledge as wisdom to make wise decisions in terms of individuals’ own circumstances. If applied, the education value chain would lead to changed mindsets and behaviour, and resolve the world’s problems.

Science was under threat. Social media and the internet provided a megaphone for fringe groups to make known their anti-science and pseudo-science sentiments to a wide number of people. It was remarkable that many cultures and peoples around the world did not believe in some of the basic concepts of science. In South Africa, informal surveys revealed that more than half the teachers did not believe in evolution and surveys at the Cradle of Humankind showed that an alarming number of people did not accept some of the basic concepts of science. One of the biggest priorities in our formal and informal education sector was to emphasise the value of science as one of the main tools to solve the very challenging problems facing the planet at this time. A few reasons why the value of science ought to be appreciate and why knowledge of the basic sciences was crucial were that science promoted evidence-based decision-making, which was the only way of making good decisions; it recognised the triple bottom line, or that the environment was just as important as financial and social good; it took humanity beyond individual decisions and bias, and encouraged groupthink and consensus, and guarded against authoritarianism.

Science and technology greatly increased the world’s computing power, even though they have brought with them the problem of Big Date where massive quantities of data were generated but not analysed.

Science and technology accelerated technology take-up, which was a feature of the very rapid technology take-up and considerable leapfrogs in accessing the internet and using cellphone technology in Africa. Involvement in science, especially due to the internet and cellphones, also promoted international collaboration, reduced isolation of people working in rural areas, facilitated collaboration across cultures, countries and continents, and promoted citizen science. The value and importance of the contributions of millions of citizen scientists in Africa needed to be recognised. Science and technology have made the world a better place and improved the quality of life of humans, although not necessarily for other inhabitants of the planet on whom humans depended for their own existence. Science helped people to be humble, understand their roles and responsibilities, recognise their shortcomings and acknowledge their ignorance.

In terms of the environmental crisis, humanity was at a crossroads and their ability to manipulate the environment was unprecedented. Humans exceeded the planet's ability to compensate for their action, and in particular to provide them with the resources they needed to survive. Humans arose from and survived through a biological process but were no longer part of wild nature. They were servants of their machines trapped in unsustainable urban environments, losing their ecological place. Humans were an integral part of nature and a valuable species but not a superior one from the ecological point of view. Every living thing has a right to live and this right was not dependent on its actual or potential use to humans but on the ecological roles that they played in the biosphere. The role of humans was to understand and work in harmony with nature and not to conquer it. Humans needed to unlearn what they had learnt before and overcome the cultural and economic constraints crafted during the industrial era using new techniques and the new tool sets that were available to them.

Prof. Bruton argued that the world was experiencing its first post-industrial revolution (not the 4IR). The most significant industrial revolution had taken place between 850 and 1492 and laid the foundation for many of the discoveries and innovations in the subsequent European industrial revolutions. The first three industrial revolutions generated benefits such as economic development, job creation, technological innovation, massive development of products and services, improved infrastructure, globalisation and advanced medical care, which only benefitted one species. These industrial revolutions also created problems. They encouraged a very materialistic culture, conspicuous consumption not only by humans but also domesticated animals, inequality, and poverty across social communities worldwide, pollution of land, sea and air, and biodiversity loss (including the ecological loss of interactions between species and ecological services that species provided), greenhouse gas emissions, climate change, human migrations, and natural resource shortages. The world continued to face the massive problems created by the first three industrial revolutions. The first post-industrial revolution was a completely different kind of revolution. It was not only a continuation of incremental industrial development but had a completely different personality. It provided to opportunity to drive a new, bigger and better step in human progress, redress past imbalances, adopt a less materialistic culture and develop a more sustainable way of life. The rest of the world had a lot to learn from Africa about sustainable living. African practices were now in the forefront of people's thinking. A number of digital revolutions had already been witnessed (such as the move from carbon-based power to distributed renewables, internal combustion engines to electric vehicles, broadcast and print internet, robots, capital, labour and land). The measures used in the West to measure wealth were being replaced by data and knowledge, big banks by smartphones, ownership by rental and the post office by courier and drones. These developments played into the hands of countries that had largely skipped the first three industrial revolutions but were taking full advantage of the first post-industrial revolution, which was characterised by having a set of digital tools, disruption and change in terms of the way things were done and as a form of social intervention and social domination that facilitated technology leapfrogs and democratised technology. This first post-industrial revolution required a major change of mindset and was capable of undoing the wrongs of the first three industrial revolutions and presented an opportunity to harness resources in an unprecedented way to solve global problems. An important aspect of the post-industrial revolution was that it was carried out by a multi-generational super organism, with a collective genius and a group intelligence that could co-create solutions to the most intractable problems. The internet not only connected people but entangled them in an unprecedented way, and connected people with the Internet of Things to provide very useful data to make predictions. Africa had a very strong role to play in taking full advantage of the opportunities presented by this first post-industrial revolution because of the continent’s rapid technology uptake in Africa, emphasising the importance of educating young African people in the basic sciences so that they would be in a position to develop innovations of their own. This century belonged to Africa with its rapid technology uptake, massive technology leapfrogs, strong social and commercial entrepreneurship, and a community that was unafraid of failure.

Prof. Bruton defined a science centre as a safe place for dangerous ideas. Although the education that took place in schools, colleges and universities in the formal education sector was very important, it had to be married with the contributions of the informal education sector, such as science centres, museums and information centres. Africa as a whole was very poorly served with only 59 science centres, 34 of these located in South Africa. Science centres were wonderful tools with pooled resources that schools needed to make full use of both on site and through the mobile science centres and outreach programmes. The centres complemented the school curriculum and played a major role in nurturing curiosity and inquisitiveness. The importance of playing was emphasised in science centres as many important concepts were learnt while playing. Prof. Bruton called for the recognition of the value of the very extensive science centre network in South Africa and its further development through Africa.

In 2016, students protested against the teaching of Western science and argued for only African science to be taught. However, there was no such thing as Western science or African science. The only science was something to which all humankind contributed. There were African contributions to science yet virtually none of these were mentioned in the curriculum because indigenous knowledge was regarded as a complementary knowledge system that complemented science, but both could benefit from each other. The school curricula needed to emphasise the African contributions to sciences and technology. This would make Africans proud and help them recognise the achievements that have been made. It was also extremely important to bring science into the mainstream of society. It had to be made as exciting to young people as music, theatre, dance and sports, as had been done in other countries.

Q&A and Discussion

Ms Niehaus remarked on Prof. Bruton's description of science centres as a safe place to meet with dangerous ideas and the right way to learn about science and technology. The methodology used by science centres was based on the latest research and the most effective ways of teaching science and technology and demystifying complex issues. Science education used to focus on physical interaction with things and scientific principles but has moved to become 'minds on and hearts on', engaging people mentally and emotionally. Multi-media, AI, augmented reality and the increased use of robotics could be provided by science centres as a pooled resource not available in individual schools. The facilities were made available to school groups and the general public either in-house or through the outreach programmes and mobile science centres. This was a very cost-effective way to get information about the basic sciences and the application of sciences across, especially to those in rural communities where schools were under-resourced. The extremely important partnership between the formal and informal education sectors had to be developed. Many of the centres featured enrichment courses for teachers. The goal of science centres was not to help learners pass exams but to make them curious and inquisitive about science and encourage them to investigate science in their own time. Science centres took advantage of the opportunity provided by the COVID-19 pandemic to develop online programmes and many of these programmes had continued in a hybrid format, and were reaching a much wider and bigger audience in South Africa and throughout Africa.

Sfiso Mofolo (Zoom Chat) mentioned that he would like to speak with Prof. Bruton about assisting an organisation to establish a science centre. Prof. Bruton agreed to discuss the matter with him.

A participant (Zoom Chat) commented that Prof. Bruton's talk was a reminder that South Africans should not move away from their history in order to understand the new developments in technology. Prof. Bruton had documented the extraordinary achievements of innovators over the years in his books, and he intended to publish more on the topic. This was an exciting time for Africa. Ms Niehaus thanked Prof. Bruton for giving hope to the people of South Africa and Africa.

REGENERATING BASIC SCIENCES FOR HEALTHCARE (PROF. ANDREW ROBINSON, EXTRAORDINARY PROFESSOR; DEPUTY DEAN: HEALTH SCIENCES FACULTY, NORTH-WEST UNIVERSITY (NWU))

As a public health physician, Prof. Robinson specialised in the environment that caused health conditions, which covered health services and communicable diseases among others, recognising the complexity of natural life. Healthcare service provision was the most complex human activity on the planet. As a medical doctor, he had several years' experience in clinical practice in urban as well as rural environments, as recognised the importance of the 'reverence for life', something that was often forgotten particularly in pandemic responses. The healthcare industry was the biggest global industry fuelled largely by the pandemic of non-communicable diseases.

In terms of South African sciences on the global scale, the community-oriented primary care approach to healthcare by Sidney and Emily Kark developed some years ago through their work in rural KZN, became a world-renowned healthcare philosophy. It was clear that Africa has the talent and that this talent could be unlocked as and when the need arose.

The South African schooling capability varied from very well-resourced private schools to very poorly resourced schools mostly in the deep rural areas. Closing the schools during the COVID-19 pandemic, particularly those in the rural areas, affected children deeply and the result would be felt for many years to come. Children experienced two years of no educational inputs, which worsened the Gini coefficient in terms of educational capacity, responsibility and talent development. The Hippocratic Oath taken by medical doctors upon qualification included the words 'first do no harm' yet the epidemic response had done a lot more harm than the epidemic itself. The epidemic response reflected little perception of the concept of the virome and the microbiome, which were both very important concepts relating to human and planetary health, and the necessity for biodiversity for general health.

The lag in the application of knowledge, often by many decades, had shown to be detrimental. The knowledge that existed about concepts such as the microbiome and the virome changed how human beings perceived themselves within the planetary environment, yet the adoption of such knowledge was still not being reflected by a lot of the current scientific effort because of knowledge lag. There was clearly a lag in the application of knowledge relating to the pandemic but the pandemic also presented an opportunity to accelerate the delay in knowledge transmission.

Clearly, there was a need for basic sciences and its knowledge and application. Healthcare provision involved all the sciences. One of the levels of healthcare provision was personal health and maintenance of wellbeing. The social determinants of health related to the SDGs and addressed the type and quality of foods and the proximity of food sources; water systems and water related diseases; air quality and its role in healthcare, and soil and its link to nutrition. The basic sciences were crucial to understanding the determinants of health but tended to be used primarily for the exploitation of the planet through a largely extractive process made obvious in the extensive mining of the Earth's minerals and its consequences, as well as the paucity of emphasis on recycling products in all forms. Agriculture was an agro-chemical industry that was extractive and destructive in terms of its reduction in biodiversity. Fishing was extractive in that it stripped the ocean floor to the point of extinctions. Employment into the industries of agriculture, mining, fishing and energy was extractive and the economies relying on these industries were dependent on their growth and driven by the concept of scarcity.

During his career as a public health physician, Robinson had been involved in managing a wide variety of epidemics and outbreaks including cholera, haemorrhagic fevers, malaria, knits and lice. Lessons could be learnt from the COVID-19 pandemic, which was a tremendous disaster within the education and health sectors. The pandemic highlighted the global acceptance of poor health status of the human population and the planet. The absence of non-communicable diseases, common cancers, arthritis and so on in Uganda during the 1960s, was confirmed to have been due to the African way of life, particular the diet. Non-communicable diseases had eclipsed communicable diseases in Africa in recent years.

Currently, the world was facing planetary changes such as changes in climate and extinctions for the first time in archaeological and palaeontological history because of human activity on the planet. Indigenous knowledge systems had shown that they were correct and that it was necessary to reduce reliance on technology and technological solutions as these could not replace life. This provided the opportunity within educational systems to make the link between education and nature recognising the application of the basic sciences towards contributing to planetary health. The problems of the planet in terms of the way that technology has been applied could be reversed. Corporate industry needed to change its focus to one that recognised that humans were part of life and not separate from it. Adapting natural science teaching to natural behavioural sciences would bring opportunities in this country to possibly resolve the post-pandemic problems, truly decolonise the educational framework and re-establish the African intellectual capital in its place.

Q&A and Discussion

Gordon Branston (Zoom Chat) commented that Prof. Robinson's presentation resonated with the transformational approach required by all sectors, framing it in the context of the UN 2030 Agenda for Sustainable Development. The basic sciences drove the applied sciences required to implement the One Health or planetary health and reinforced the ambitions of the SDGs to anchor health and development, recognising that good health depended on and contributed to other development goals underpinning social justice, economic prosperity and environmental protection.

ADDRESSING THE CONUNDRUM: PLANET EARTH – MAXIMUM CARRYING CAPACITY (DR JENITHA BADUL, SENIOR MANAGER/POLICY ADVISOR: SUSTAINABILITY PROGRAMMES AND PROJECTS, DEPARTMENT OF FORESTRY, FISHERIES AND THE ENVIRONMENT (DFFE))

Planet Earth definitely had a maximum carrying capacity and there were projections of when this maximum would be reached. Business-as-usual activities impacted on how the world needed to behave in the coming years.

It was important to understand the relationship between basic natural sciences, with physical and biological sciences having the primary function of generating knowledge through observing natural phenomena. This created the foundational knowledge required that was usually taken up by the applied disciplines and applied in biotechnology, microbiology and so on. Credit needed to be given to the basic sciences for generating new knowledge.

From the sustainable development perspective, the ideal balance proposed was based on the pre-industrial period where the amount of carbon emissions per annum was calculated at 280 parts per million and the global average temperature increase was less than one degree Celsius. Sustainable development happened in the intersection between economic, social and environmental imperatives. Subsequently, many of the planetary boundaries have been compromised. In terms of the intersection between sustainable development, climate change and the basic sciences, anthropogenic activities had a significant impact on Earth systems. The informal term used for this was 'the anthropogenic era or period' but the term has not been formally accepted, possibly because human beings were responsible for the changes currently being seen.

With regard to the altering Earth's systems, some of the direct impacts that have been seen included erratic weather patterns, the impact on carbon sinks and exceeding the planetary boundaries. The implications were that the existing body of knowledge needed to be reconsidered, especially the basic knowledge that was put in place by the basic sciences, because human activity was influencing the natural systems over the centuries. Nine planetary boundaries had been identified although this approach was widely criticised due to the manner in which exceeding each of the planetary boundaries was considered by each country. Four of these boundaries (climate change, biodiversity integrity loss, altered biogeochemical cycles and land system change) had already been exceeded globally. Most of the processes could not be reversed, but their impact on the planet could be slowed down. Global agreements forced countries globally to agree to certain terms and conditions to ensure that they were on a trajectory to slow down the impact made on the planet thus far.

South Africa's position in approaching sustainable development was based on governance, with economic and social factors being encompassed within the environment. The economic pillar of sustainability impacted greatly on the social as well as the environmental imperatives. The global drive to maintain temperature to less than two degrees Celsius would possibly not be achieved if rapid industrialisation continued in the coming decades. It was necessary to understand what the safe operating space was given the fact that four of the nine planetary boundaries had already been compromised. The Inter-governmental Panel for Climate Change (IPCC) reported observations across both the Global North and the Global South and came up with potential recommendations that should be followed diligently by countries as a result of anthropogenic activities as the basis for their impact.
Developing countries as well as emerging economies wanted to industrialise at a pace that the planet was unable to absorb. As a result, the global challenge faced currently became everyone's business. Behavioural changes on a personal, national and global level were essential. People needed to realise that their behaviour and activities have compromised environmental aspects and resulted in environmental degradation, natural resource depletion and challenges in managing waste. One of the main differences between climate change and sustainable development was that climate change identified the social as well as the environmental imperatives whereas sustainable development traversed the social, environmental dimensions and economic imperatives.

It was projected that the 8 million mark with regard to the global population would be reached by the 15th of November 2022 and that the population would have increased to 10.4 billion by 2050 when the planet would have exceeded its maximum carrying capacity. There was uncertainty around what the impact of this on the dynamics and systems, but there was no doubt that it was a cause for concern. Much had been said about sustainable development, resource efficiency and low carbon development over the last 15 to 20 years, but proactive steps had not yet been taken to address the desperate calls for people to change their behaviour and activities.

Some of the key events (such as the melting of the polar icecaps and a subsequent rise in sea level) that were taking place were irreversible. Some small island states were concerned about the rising sea levels and were looking at natural barriers that could protect them, transitioning to low carbon imperatives and embracing it from an industrial perspective. Cities such as New York and Venice have become known as sinking cities as a result of the sea level rise. In terms of biodiversity loss, species extinction seemed to be happening more often recently. This raised questions about what people had to do in order to sustain life on Earth and what key measures needed to be put in place to slow down what has been happening over the past decades and to change behaviour.

The damage done by the industrialisation of the developed countries was primarily responsible for the current situation, yet developing or emerging economies continued to become industrialised in an attempt to be compatible with the Global North. The compromising point was that industrialisation had to be undertaken in a responsible manner. SDG#17 talked to collaboration, technology transfer, innovation as well as the means of implementation.

Possible ways to ensure that the planet’s maximum carrying capacity would not be exceeded looked at a sustenance perspective or a more conservative approach going forward, whether the planet was able to survive the impact of human consumptive, productive and behavioural patterns, and whether sustainable development (addressing environmental, social and economic imperatives) could be the ‘silver bullet’. A solution would require a multi-disciplinary approach and common but differentiated responsibilities. The means of implementing change in order to mitigate climate change had moved from the green economy agenda to linear and circular economy models pursuing sustainable consumption and production. While new bodies of knowledge were being generated, the implications of application and uptake had to be understood. A realistic approach was needed in determining the implications for the developing world/emerging economies, and had to be carried out in a responsible, resource-efficient and inclusive way.

Sustainable development could be considered as a response provided there was adequate capacitation, resource efficient business operations/practices, technology transfer, innovation, implementation at scale, unlocking of financial resources and management of population increase. There was an ongoing debate on global platforms regarding access to finances and the responsibilities of developed countries towards developing countries to ensure that the next generations would inherit an intact planet. The agreement at the global level (through the annual UN Framework Convention on Climate Change Conference of the Parties (UNFCCC COP) negotiations) ensured that the Paris Agreement accommodated the fund. However, it had taken a long time for the fund to reach the first $100 billion and as a result the trickling down effect to the least developed countries was taking much longer than necessary. It was unclear whether the targets would be achieved by developed countries at the end of the day. Nonetheless, other financing mechanisms had come to light and developed countries have agreed to take a certain amount of responsibility and inform the necessary climate resilience development within their countries by themselves.

The DFFE has been working with municipalities to capacitate them around green bonds, ensuring that they could take on loans and follow a green trajectory in terms of development at the municipal level. National Treasury already had an enabling policy environment to ensure that municipalities could actually take up and issue green bonds. This brought in an additional dimension of monitoring and evaluation and encouraged better governance and financial management by municipalities. In addition, there were concessional loans and Germany along with four other countries had agreed to double up their contributions to South Africa's Just Energy Transition programme. South Africa would have to take on loans in foreign currencies that brought with them debt in the medium- to long-term. Given the recent announcement by the Minister of Finance on the country's economic outlook, there was no room to take on or explore the option of taking on additional debt and trying to service it and it was crucial to find solutions that worked for the country within the current environment.

Q&A and Discussion

Susan Kone (Zoom Chat) asked about how the solutions offered applied to rural communities. Dr Badul indicated that rural communities have been approached from an agricultural perspective and a guideline on climate smart agriculture was developed through one of the DFFE's programmes. The DFFE has also worked with subsistence farmers in seven of the provinces at a pilot level looking to ensure that their commodities have access to markets and that they produced the commodities, and providing them with the necessary opportunities. The DFFE also facilitated a dialogue on the potential for agricultural commodities from an export perspective. The sudden imposition of rules and regulations by the European Union (EU) recently, to address the value chain from the farm gate until the product reached the shelves in Europe, was not helpful as it added another expenditure that many farmers might not have envisaged.

Prof. Bruton asked about the calculation of the carrying capacity of the planet and whether it should not be about how the people lived and the extent to which they used resources, their large or small carbon footprint and so on. Dr Badul indicated that the modelling for the carrying capacity of the planet was based on similar system modelling to that used for economic projections. She agreed that there were other factors that should influence the maximum of between 9 and 10 billion people on the planet. The fact that people would have transitioned to much smaller ecological or carbon footprints over the years needed to be taken into account. Many European countries had timelines attached to reaching their maximum carbon footprints. These projections would probably be informed by the transition to a low carbon society and this aspect would influence the maximum capacity by 2050.

Susan Kone (Zoom Chat) asked in relation to the increasing population whether it was possible to attend to the young girls giving birth and the Soweto pregnant girls saga. Dr Badul suggested that the issues called for more education so that the girl child was able to make informed decisions.

ABSTRACTING DIAMONDS FROM DIRT (DR KHANGELANI SIBIYA, MATHS AND SCIENCE EDUCATOR, WHERE TO START (WTS) MATHS AND SCIENCE)

Dr Sibaya's presentation focused on the role of the teacher in advancing maths and science. Teachers have been tasked with producing the future leaders for this developing country. Teachers were a catalyst of change, progress and future communities. Their role in society was vital but it was up to them to ensure that the work they did was recognised and appreciated. The problem with teaching maths and science was related to the following:

- Declining numbers, as learners were not motivated to study maths and science due to a high percentage of learners failing these subjects. Learners chose this stream with the understanding that these two subjects were very difficult, even for the teachers.
- Learners struggled with numerics. Over the past five years, significantly less than 50% of those who took the matric final exam wrote maths as a subject. The majority of learners chose maths literacy or technical sciences rather than pure maths.
- The low pass rate. In 2018, 37% of the 270516 learners who write the matric maths exam passed with 40% and above. Those who passed well had a better chance of being accepted to a university.
- The high cost. Maths had the lowest output for subjects classified as gateway subjects and considered critical to the economy and development.

Solving these problems required addressing the basics. Dr Sibaya was raising funds to build the biggest virtual classroom and a mobile laboratory so that learners at schools around the country would be able to see mathematical formulas coming to life and the theories taught in class being proven. The education system's weak record in maths and science was primarily due to the lack of infrastructure for illustrating mathematical theories in practice. Partnerships had to be formed that would advance science and technology from the ground up.

Dr Sibaya created a environment conducive to teaching that allowed learners to feel free and relaxed and to interact during the lessons. Learners were often afraid to ask questions or seek clarity on a lesson. Teachers had to be approachable as this made it easier for learners to feel relaxed and confident enough to ask questions. Teaching should focus more on the underlying skills than on merely answering the questions in past exam papers as applying the skills would help learners excel in maths and science. Dr Sibaya also drew up summary notes focusing on the skills required to answer questions and theses were shared with all learners across the country at no cost. When going through past exam papers with learners, Dr Sibaya simply focused on the structure of the paper and not the specific questions, noting the different cognitive levels and connecting these with the exam guidelines and the Curriculum Assessment Policy Statements (CAPS) document. It was important for teachers to motivate the learners when teaching. Most learners tended to convince themselves that wold not pass an exam before they had even written the exam. In such instances, Dr Sibaya simply pointed out how many marks they should aim to score for each question in order to achieve the pass mark they aspired to. Learners set targets for the marks they aimed to get and worked according to those targets. These techniques helped dispel the fear about the difficulty of the subject. Learners were kept fully occupied in class. They were involved in all the lessons, participated in the class and made presentations to the class. Learners got to practice mathematics under the supervision of the teachers and the teacher assessed their skills in answering questions. Through making presentations, any misconceptions were corrected by the teachers and the other learners who were encouraged to think critically and learn from the discussions.

Dr Sibaya discovered a way to integrate social trends in his teaching practice. This helped him produce high numbers of learners who excelled in maths. Young people enjoyed Dr Sibaya's lessons and more so when he used sports and music to illustrate maths and science concepts and their application in everyday life. These methods had shown to work well. At the beginning of each year, the learners were separated into groups according to their maths and science capabilities. This prevented them from becoming frustrated in class. In the absence of a laboratory, science experiments and maths concepts had to be demonstrated in the classroom through assimilations to help learners visualise the concepts being taught and relate them to real world situations.

The science and technology community needed to be intentional about populating its space with brilliant young minds. This meant that tools had to be made available for the 'abstraction of the diamonds that were hidden in the rocks and hard places, the dusty streets of townships and rural areas'. In other words the teaching approach had to be more relevant, interesting and funny to be able to reveal or expose the learners' hidden skills through by using appropriate teaching methods. Bringing the theory into practice was a challenge on its own. Children needed to see the theories being brought to life. South Africa has produced some of the most amazing brains in science and technology and made a valuable contribution to the world. Children needed to recognise this and see the potential in themselves, and interact with role models more often.

Q&A and Discussion

A participant commented that Dr Sibaya's presentation motivated him in his PhD research, which focused on studying physics using mathematics knowledge. His biggest challenge was to get teachers to attend professional development workshops due to the fact that the majority of the schools only have one science teacher to teach all the grades. The Department of Basic Education (DBE) instructed these teachers to give the learners extra lessons and this meant that they had no time to attend workshops. He asked for Dr Sibaya's advice about a possible intervention such as virtual classrooms to alleviate the pressure on science teachers. Dr Sibaya responded that the best solution for these very busy teachers would be that they do their teaching in virtual classrooms and use pre-recorded lessons. This way, one teacher could assist many learners at different times and locations.

Mankwe Mojapelo asked Dr Sibaya for his view on the consequences of the decision taken by a private school to run classes in the afternoons in addition to the mornings and allow learners to choose to attend either the morning or afternoon classes. Dr Sibaya did not agree with the school's decision because having fixed hours for class taught children self-discipline and time management, which would benefit them at university and in the workplace. School prepared children for the work environment.

Ms Niehaus mentioned that the inclusion of robotics and coding in the curriculum had been discussed at the recent discussion forum and asked whether Dr Sibaya had taught these subjects or knew of other teachers' experiences in this regard. Although he had not taught these subjects, Dr Sibaya pointed out that many learners were disadvantaged by teachers not teaching according to the standards and this problem could be resolved by using robotic systems to ensure the standardisation of teaching. It would be difficult to teach robotics and coding to children in poorly resourced schools. The inclusion of these subjects in the curriculum would therefore have the unintended consequence of increasing inequality across schools in the country. He mentioned that the inequalities in the education system were highlighted during the COVID-19 pandemic as many teachers were not capacitated to give lessons online and data and connectivity were insurmountable issues, particularly in rural areas.

A participant asked Dr Sibaya how students could be equipped to transition from school to university (or university to the workplace) where there was interaction with peers from well-resourced institutions. Dr Sibaya responded that some companies gave talks to learners to prepare them for university and the workplace, and these issues were also addressed in Life Orientation classes.

Mankwe Mojapelo related her personal experience of the transition from school to university and suggested that the DBE could do more to prepare students for the difficult adaptation to university, especially those from rural areas and resource-poor schools. Dr Sibaya agreed that more could be done in this regard adding that Life Orientation was not sufficient in some aspects. Career guidance was vital and should be enhanced to complement Life Orientation. Usually, the young teachers had attended university and were able to use their experience to guide learners. On the whole, teachers played an important role in assisting learners with applications to tertiary institutions and in preparing them better for the university environment.

Ms Niehaus asked Dr Sibaya's view on teaching children about sustainable development. He indicated that teachers had to teach about sustainable development. Teaching a subject was not only about the concepts but also about addressing the subject holistically and in respect of the life of a child in its entirety. Teachers were also expected to teach children to be critical thinkers so that they were able to resolve any problem they were faced with in life.

Gordon Branson (Zoom Chat) asked how to develop the basic skills of people who had not even benefitted from primary education and who eked out a meagre living in insecure, low productivity jobs in the informal sector, and whether there was a transformative vison that aligned with the SDG principle of leaving no one behind.

Dr Sibaya indicated that he and others were working with teachers to share teaching approaches for maths and science. The DBE held many workshops to support and upskill teachers, but more workshops were needed especially in the rural areas.

Q&A AND DISCUSSION

Ms Niehaus asked the speakers how they would reconcile the reality of many people living in circumstances of poverty in remote rural areas without good connectivity and struggling with education, with the country's ideals. Prof. Robinson mentioned that the NWU's programme called 'Social Greenhouse' was a social innovation interface that expedited the adoption of innovative solutions within communities. It unlocked and enabled the university's presence and a process of optimising sustainability in every community. The programme was tested in informal settlements and rural communities. Wealth was measured in many components, not just monetary, and there were always assets in a community. The focus was shifted to work collaboratively and within the natural paradigm of recognising Ubuntu instead of working competitively. The world has reached the cul-de-sac of technology by recognising that it was not a solution. The medical faculty at NWU was working closely with the university's industrial engineering group to establish an ethical grounding at the onset of technological ideas so as to embed ethics in the technology. It was evident that the state of health has not provided a healthy planet and a healthy population. The COVID-19 pandemic was so severe because the virus found a very sick population. It was essential to recognise this and shift the technological focus to solving the health, nutrition and other big problems. Much could be repaired with the appropriate reverence for life. Everyone could contribute very simply by making the right choice of food and deciding what industry to support. Individuals' choices translated to consumer demand that brought changes in the market. The dynamic of change moved a lot quicker due to social media. Democratising information was very helpful, especially for the health sector, but it was very important to give correct public health information during any outbreak. Information should not get side-tracked as was seen during the pandemic when some of the regulations and attitudes were spurned by fear preventing any discourse in terms of a rational response to the pandemic.

Prof. Robinson was asked to explain the microbiome and the virome. The microbiome was very important to human health and wellbeing. Within the human gut, there were a multitude of bacteria that were essential for life and assisted with the digestion of food. The more traditional food one consumed the more varied the microbial flora of the gut and intestines were. A Western diet produced severely diminished microbiome diversity because the diet was depleted in many nutrients and had a lot of other additives, toxins and preservatives. It was possible to predict what illness people on a Western diet would suffer from based on their diet. Industrialised agriculture's mono-cropping was very destructive to diversity and contributed significantly to the reduction and the extinctions of many traditional crops. Modern farming practices accelerated after the Vietnam War with the shift of the military chemical industry into the agro-chemical industry. Chemicals were used to eradicate weeds allowing only genetically modified organism (GMO) crops to thrive. In so doing, the soil was depleted of its vital micro-organisms, leaving only the chemical known as glyphosate (an antibiotic of form). The food industry was based on this poison that affected humans by disrupting the tight junctions in the gut and causing illness. The virome was an assemblage of viruses associated with a particular ecosystem or organism. Viruses existed on the planet long before life began and it was their amalgamation that enabled life. More than 50% of the human genome came from viral inserts and there were more viruses than there were stars. Viruses were part of life and a symptom of the state of health of the species and state of the planet.

CLOSURE

Ms Niehaus presented a brief overview of the second day's presentations, as follows:

- Prof. Bruton shared his inspiration that South Africa and Africa were innovative and that there was hope in Africa for the world. He gave numerous examples of this and suggested that the main benefits of the basic sciences were that it taught people to think rationally and objectively, and encouraged people to be sceptical and ask questions that challenged current knowledge. Climbing the innovation ladder from low-tech to high-tech was important and should be happening in Africa. In terms of the environmental crisis, the planet's ability to compensate for people's actions had been exceeded. This was expanded on by Dr Badul in her presentation on how the planet's carrying capacity was being exceeded on many points.

- Prof. Bruton’s understanding that people have removed themselves from their ecological place and were totally out of touch with nature was reiterated by Prof. Robinson.
- Prof. Bruton challenged the notion of the 4IR and instead suggested that the world was going through its first post industrial revolution, which he regarded as a good opportunity for Africa to learn, develop and devise new ways of doing things.
- Prof. Bruton supported the interactive science centres as they were the real way to teach maths and science, particularly as they allowed learners to experience these subjects outside of the pressures of school. Dr Sibaya also spoke about the fact that science centres showed children the exciting side of maths and science and allowed them to engage with the learning material in a fun way. Minimising the fear of maths and science that some learners experienced allowed them to concentrate better and improved their performance.
- Prof. Robinson raised an interesting point about the knowledge lag in that knowledge took many decades to have effect. There was an opportunity to accelerate the development and communication of knowledge in this new digital era, which Prof. Bruton suggested would make the greater effect of science more accessible to all.
- Dr Badul spoke about the dire situation with regard to over-population and excessive use of the planet’s resources. Some of the changes that humans have brought about on the planet were irreversible and the only way left to slow down the damage that was done was to minimise impact on the carrying capacity factors.

Ms Niehaus thanked the participants for their attendance and contributions to the discussions, and the speakers for sharing their insights, knowledge and experience, which contributed to the thought-provoking and rich conversations.

Outcomes of this forum would include a media release summarising the issues covered during the two days’ discussions, video recordings and a proceedings report, which would all be available in due course at www.nstf.org. In addition, issues and themes highlighted during the proceedings, as well as a few recommendations specifically with regard to STEM education, would be taken forward.

ACRONYMS

4IR	Fourth Industrial Revolution
AI	Artificial intelligence
ATLAS	A Toroidal LHC Apparatus
CERN	European Organization for Nuclear Research
COVID-19	Coronavirus disease of 2019
CUT	Central University of Technology
DBE	Department of Basic Education
DPME	Department of Planning, Monitoring and Evaluation
DUT	Durban University of Technology
EDI	Electrodeionisation equipment
IPS	International Science Programme
KZN	KwaZulu-Natal
LHC	Large Hadron Collider
NSTF	National Science and Technology Forum
NWU	North-West University
RANR	Radially aligned nano-rutiles
SANSA	South African National Space Agency
SDG	Sustainable Development Goal
SPEI	Standardised precipitation evaporation index
UN	United Nations
UN	United Nations
WHO	World Health Organisation
Wits	University of the Witwatersrand
WLCG	Worldwide LHC Computing Grid

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CUT	Miss	Seithati	Semenokane
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